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DOCTOR OF PHILOSOPHY

Factors Affecting Maintenance Labour Productivity in the Building Industry

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FACTORS AFFECTING MAINTENANCE LABOUR PRODUCTIVITY IN THE BUILDING INDUSTRY

by

Abubaker Gaber Abubaker

A thesis submitted in fulfilment of the requirements
for the Degree of Doctor of Philosophy in the
Division of Civil Engineering of
the University of Dundee

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Nomenclature

AA	-	Availability Analysis
AC	-	Appearance Consequences
BFC	-	Building Futures in Construction
BIFM	-	British Institute of Facilities Management
BMI	-	Building Maintenance Information
CBM	-	Condition-Based Maintenance
CDRMS	-	Construction Division Repair & Maintenance Section
CIBSE	-	Chartered Institution of Building Services Engineers
CMMS	-	Computerised Maintenance Management System
CSI	-	Cost Significant Item
DETR	-	Department of Environment, Transport and the Regions
DT	-	Destructive Testing
DTI	-	Department of Trade and Industry
EC	-	Economic Consequences
EVM	-	Earned Value Management
FBM	-	Failure-Based Maintenance
FMEA	-	Failure Modes Effects Analysis
FMECA	-	Failure Modes Effects and Criticality Analysis
FM	-	Facilities Management
FTA	-	Fault Tree Analysis
HC	-	Health Consequences
HMS	-	Hillcrest Maintenance Services
IBM	-	Inspection-Based Maintenance
IFMA	-	International Facilities Management Association
ILS	-	Integrated Logistics Support
ISO	-	International Standards Association
LCA	-	Life Cycle Assessment
LCC	-	Life Cycle Costing
LORA	-	Level of Repair Analysis
MA	-	Maintainability Analysis
MCA	-	Multi Criteria Assessment
MIL-STD	-	Military Standard (US Department of Defence)
NC	-	No Consequences
NDT	-	Non-Destructive Testing
NM	-	No Maintenance
PFI	-	Private Finance Initiative
PI	-	Productivity Index
PI AWC	-	Amount of Work Completed Productivity Index
PI CoM	-	Cost of Material Productivity Index
PI EH	-	Earned Hours Productivity Index

PI EV	-	Earned Value Productivity Index
PM	-	Preventive Maintenance
PT & I	-	Predictive Testing and Inspection
RA	-	Reliability Analysis
RCM	-	Reliability Centred Maintenance
RICS	-	Royal Institution of Chartered Surveyors
RM	-	Risk Management
RWG	-	Rain Water Goods
SA	-	Supportability Analysis
SC	-	Safety Consequences
SoR	-	Schedule of Rates
SMV	-	Standard Minute Value
STD	-	Standard Deviation
TBM	-	Time-Based Maintenance
TLBM	-	Through Life Business Model
TSI	-	Time Significant Item
UK-DEF-STAN	-	United Kingdom Defence Standard
VI	-	Visual Inspection
VM	-	Value Management
WLC	-	Whole Life Costing
WLV	-	Whole Life Value

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And finally, to the memory of my son Yusef and my brother Mohamed who supported me and encouraged me to pursue this PhD research, I wish you were here to see it completed and to share the joy with me.

Declaration

I hereby declare that this thesis has been compiled by me, that it is a record of work completed by me, all references cited have been consulted by me and that it has not previously been accepted for a higher degree at this University or any other institution of learning.

A G Abubaker

Certificate

This is to certify that Abubaker Gaber Abubaker has done this research under my supervision, and that he has fulfilled the condition of Ordinance 13 of the University of Dundee, so that he is qualified to submit for the degree of Doctor of Philosophy.

Professor R.M.W. Horner

Emeritus Professor of Engineering Management

Abstract

The research explored ways for improving maintenance labour productivity and reducing maintenance costs. This can be achieved through reducing the number of maintenance activities and by improving the productivity of labour carrying out repair and maintenance tasks.

The research established that Integrated Logistics Support (ILS) techniques, in particular, Failure Modes and Effects Analysis (FMEA) and Reliability Centred Maintenance (RCM) could be applied to building systems, in this case to the maintenance of Rainwater Goods to identify the most applicable and cost effective maintenance strategy. As a result it was found that while 60% of failure modes identified could be rectified by employing a Failure-Based Maintenance strategy, 40% of the failure modes require a Condition-Based Maintenance strategy which is not currently applied.

Labour productivity is a subject of tremendous interest to research in the construction industry; the study found however, very little research on the productivity of labour in building repair and maintenance operations. It was found that measurement of building maintenance labour productivity has not been the focus of any previous studies. Indeed no measures of productivity for building maintenance were identified. Having considered a number of alternative measures, the research identified the productivity index expressed in terms of Estimated Hours/Actual hours to be the most appropriate measure of labour productivity in repair and maintenance operations. Using this measure, it was established that labour productivity is impacted by a number of variables including task performance, labour performance, material usage and seasonal variability.

Among the objectives of the research was to identify the factors influencing labour productivity. Through a survey questionnaire, it was possible to identify the factors that have the greatest impact on maintenance labour productivity; these were the level of skills and motivation of workmen; quality of information and work instructions; labour turnover and absenteeism; availability of tools and material, and access to the job site.

The analysis of historical repairs data from two building repair and maintenance organisations revealed that during the performance of the same tasks, one of the data sources was almost 25% more productive than the other. The research has established that there is a potential for improving labour productivity carrying out building repair and maintenance.

Chapter 1: Introduction and Problem Statement

1.1 Introduction

A great deal of research has been conducted on construction labour productivity over the years; however, research into maintenance labour productivity is scarce. The position and influence of the construction industry on the national economy is very significant with the total construction output in 2013 estimated at £112 billion (Office of National Statistics, 2014). It is widely recognised that to evaluate the costs of buildings on the basis of initial costs alone is unsatisfactory (Ashworth, 1999). Whole Life Costing of a building incorporates the total costs associated with it from inception to eventual demolition. A major portion of these costs relates to repair and maintenance costs. In the UK repair and maintenance works for housing and non-housing sectors was estimated to be about 39% of the total construction output in 2013. The total expenditure on repair and maintenance in the UK in 2013 was estimated at £44 billion (Office of National Statistics, 2014). Given the annual expenditure on repair and maintenance any opportunities for productivity improvement will have a significant impact on the industry.

Maintenance and operation costs are usually more difficult to predict than other building expenditures. Operating schedules and standards of maintenance differ from one building to another; there is large variation in these costs even for buildings of the same type and age. Maintenance provision is an important aspect of the total ownership costs of buildings. Research indicated that the cost of operating and maintaining a building can be approximately five times the cost of capital over the life of the building (Evens *et.al*, 1998). Although Hughes *et al*., (2004) concluded that this ratio is not based on any real research findings; they did assert however, that the idea of the ratio for a particular building serves to focus attention of owners on improving building quality to reduce maintenance costs over the life cycle of a building. Other researchers state that occupancy costs differ from one building to another and are determined by the size, shape, layout, location and intensity of use of a building (Seeley, 1996; BMI, 2002). Despite this it is still the case that maintenance cost histories for individual buildings are poorly documented. Consequently it is almost impossible to build an adequate picture of maintenance cost performance (Bromilow and Pawsey, 1987; Boussabain and Kirkham 2004, Maranjak 2004, Al-Hajj 1991).

It is therefore rather difficult to develop an accurate estimate of maintenance cost performance. Horner *et.al*, (1997) argued that to ensure continued, safe and profitable use of a building at an acceptable level of satisfaction only essential maintenance should be carried out or when there is the possibility of extending the useful life of the elements of the building. Horner *et.al*, (1997) further argue that the objective of any approach to maintenance management should be "to prevent, to minimise and to repair building defects by enhanced planning and implementation using appropriate materials and tools at the right time and minimum total life cycle cost".

Maintenance cost can be minimised a) by ensuring that the right tasks are carried out, and b) by ensuring that the right tasks are carried out at a minimum cost. Minimising the number of maintenance tasks will lead to a reduction in maintenance costs. In this project, Integrated Logistics Support (ILS) techniques, in particular, Failure Modes and Effects Analysis (FMEA) and Reliability Centred Maintenance (RCM) will be applied to a selected case study to explore the extent to which ILS could optimise maintenance strategy.

In addition, maintenance costs may be reduced by minimising the cost of executing maintenance tasks. This could be achieved through selecting appropriately trained tradesmen, and adequate planning of maintenance resources. This project analyses historical repair and maintenance data provided by two local housing repair and maintenance organisations with a view to determining the variability in productivity levels during the performance of routine repair and maintenance tasks. Due to the labour intensive nature of the construction industry in general and the repair and maintenance operations in particular, and because labour is the most significant variable, this research project will concentrate on the productivity of labour.

Reducing or controlling the impact of the factors that influence labour productivity is therefore very important. This research seeks to identify the factors influencing maintenance productivity and rank these factors in order of importance with a view to identifying opportunities for improving productivity.

As a result of the study of repair and maintenance data, productivity improvement issues derived directly from the results of the data analysis will be identified.

1.2 Problem Statement

The costs of building maintenance can account for a significant proportion of the whole life cycle costs of a building. In order to reduce the cost of maintenance, the performance and the Life Cycle Costs of buildings from inception and its continuous monitoring and management will be required. This includes ensuring that the right type of maintenance is carried out (selecting the appropriate and cost effective maintenance strategy) and that the selected maintenance strategy is carried out in the most efficient way (labour productivity). Labour productivity in maintenance operations is affected by a number of factors. The effects of these factors vary from job to job and from one person to another, resulting in different productivity levels. This research seeks to throw light on the variation in productivity for similar repair jobs and the causes of this variation. Understanding variation and its causes should provide opportunities for improvement.

1.2.1 Research Aims

The aims of the research are to explore ways for improving maintenance labour productivity and reducing maintenance costs by 1) reducing the number of maintenance activities; and 2) improving the productivity of labour. The first aim is addressed in Part 1 of this thesis, the second in Part 2.

1.2.2 Research Objectives

The first aim of the research will be met by investigating to what extent Integrated Logistic Support (ILS) could help to optimise maintenance strategy. Through the use of a case study, the objectives are to:

- Carry out a review of the literature to explore the use of ILS within the construction industry in general and its application to building maintenance in particular.
- Examine historical records for repairs to Rainwater Goods as an example in order to determine the current maintenance strategy.
- Develop the physical model of the rainwater goods system to be examined, identifying its parts and identifying their functionality.
- Carry out Failure Mode and Effects Analysis (FMEA) to identify:
    - Ways in which a failure mode of the system elements can occur,
    - The possible causes of the failure modes and
    - The failure mode's potential impact on the system functionality.

- Carry out Reliability Centred Maintenance (RCM) analysis in order to identify the appropriate and cost effective maintenance regime for the system.

The second aim of the research can be met by identifying the factors influencing maintenance labour productivity and examining the variability in productivity levels while carrying out basic repair and maintenance tasks. This may be broken down into the following objectives.

- Identify the factors influencing maintenance labour productivity and rank these factors in order of importance.
- Identify the main trades and maintenance tasks that have the greatest impact on repair and maintenance activities,
- Identify and examine the amount of variability in productivity levels during the performance of basic repair and maintenance tasks,
- Investigate the possible remediation measures required to improve labour productivity.

1.3 Thesis Layout

The thesis consists of an introductory chapter **(Chapter 1)** to present an introduction to the research project, the problem statement and the aims and objectives of the research. Thereafter, the thesis is structured in two parts covering different aspects of the research problem.

Part one deals with the role of Integrated Logistics Support (ILS) in optimising maintenance strategies. This part uses the maintenance of Rainwater Goods as a case study and will act as a natural precursor to discussing labour productivity at the basic task level.

Part two examines labour productivity during the performance of repair and maintenance tasks.

- **Chapter 2** – contains the literature review of the main topics to be discussed in the thesis. It starts with a broad discussion of whole life costing, life cycle costing and facilities management in order to set the scene for discussing building maintenance and related issues. The chapter is then divided into two parts, part one discusses the role of Integrated Logistics Support (ILS) in optimising maintenance strategy including defining ILS and its related techniques. Part two discusses the topic of productivity, its measurement and improvement with particular emphasis on building maintenance labour productivity. The literature review identifies the gap in knowledge and justifies the research aims.
- **Chapter 3** – similar to chapter two is divided into two parts; part one presents and discusses the methodology to be followed in the application of ILS techniques to the analysis of the case study to achieve the objectives of part one. It also discusses any necessary modifications to processes in order to achieve the objectives. Part two discusses the methodological approach followed in the course of the research for measuring building maintenance productivity and the tools and/or techniques used. Part two also discusses the methodology followed for the design and administration of a survey questionnaire on the factors influencing maintenance labour productivity.
- **Chapter 4** - discusses the application of ILS techniques to the chosen case study. It introduces the case study, describes the steps taken to implement the ILS techniques, and presents the results of the case study.

- **Chapter 5** - discusses the factors influencing maintenance labour productivity and presents the results of a survey questionnaire on the topic.
- **Chapter 6** - describes the process of collecting the responsive repairs data including description of the data sources and describing the steps taken to prepare the data for analysis.
- **Chapter 7** - discusses the various stages of analysis carried out on the data in order to identify the variability in productivity levels while carrying out basic repair and maintenance tasks. The chapter also presents the results of the analysis and the research findings.
- **Chapter 8** - highlights the potential for improving maintenance labour productivity in accordance with the research findings.
- **Chapter 9** - presents the major conclusions of the research and highlights the potential for further future research on the subject area.

Chapter 2: Literature Review

2.1 Introduction

It is accepted that the costs of building maintenance can account for a significant proportion of the whole life cycle costs (Boussabaine and Kirkham, 2004). Figure 2.1 indicates the contribution of repair and maintenance to the total construction output during 2013. Reducing these costs requires consideration of the performance and cost-in-use (Life Cycle Costs) of projects from the outset and their monitoring and management during use. Maintenance, cleaning and running costs such as energy, utilities and management, it is argued, should be monitored against those anticipated and compared (benchmarked) with those experienced by similar organisations occupying similar buildings (CIB, 1996).

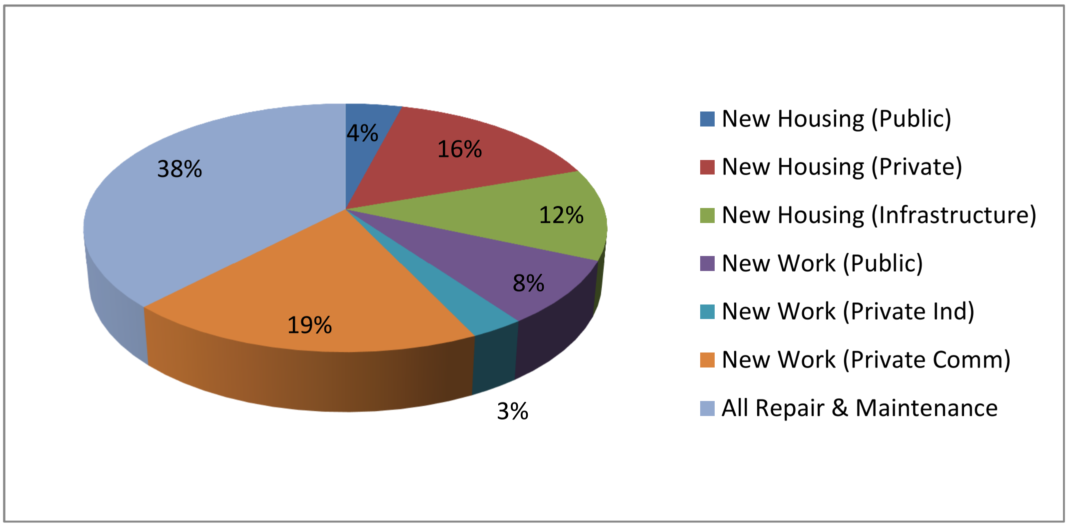

Figure 2:1 Construction Output 2013 (Based on figures from ONS 2014)

Despite the significant contribution of maintenance provision to whole life cost, maintenance cost histories for individual buildings are poorly documented (Bromilow and Pawsey, 1987). It is therefore rather difficult to develop an accurate estimate of maintenance cost performance. The operation and maintenance phase of Life Cycle

(Facilities Management Phase) is usually the longest and often the most neglected phase in the life cycle of constructed facilities. The activities undertaken to operate or/and maintain a building can have an impact on its service life.

This research aims to explore ways for improving maintenance labour productivity and reducing maintenance costs. Minimising the number of maintenance tasks will lead to a reduction in maintenance costs. Within the construction industry, it is recognised that over the life cycle of many buildings, an owner will meet maintenance and repair costs equalling two or three times their initial capital costs (Spedding, 1994). This has made it necessary to improve the ways in which building maintenance is implemented and managed and to introduce and apply new engineering techniques for selecting the most cost effective maintenance strategy in order to ensure that the cost of maintenance of a building is kept to a minimum. In part one of this research Integrated Logistics Support (ILS) techniques, in particular, Failure Modes and Effects Analysis (FMEA) and Reliability Centred Maintenance (RCM) is applied to a selected case study to explore the extent that Integrated Logistics Support (ILS) could help to optimise the maintenance strategy.

Building repair and maintenance is a labour intensive activity; part two of the research is concerned with improving the productivity of labour. El-Haram and Horner (2002) describe maintenance costs to include all expenditure on maintaining the building up to an acceptable standard. Improving the productivity of the direct maintenance resources such as material, labour, and plant and tools needed for the successful completion of the task, will have the effect of reducing maintenance costs. El-Haram and Horner (2003) concluded that there is a shift from cost driven maintenance strategies to consequence driven maintenance strategies.

The literature review presents the major themes that relate to labour productivity and its measurement and improvement, as well as attempting to establish the extent to which maintenance labour productivity has been explored by other researchers.

2.2 Whole Life Cost and Value

2.2.1 Whole Life Value

Whole life value (WLV) encompasses economic, social and environmental aspects associated with the design, construction, operation, decommissioning, and where appropriate, the re-use of the asset or its constituent materials at the end of its useful life. WLV takes account of the costs and benefits associated with the different stages of the whole life of the asset (Mootanah, 2005). The UK Government highlighted that all major public sector construction procurement must be based on whole life value for money. Although not compulsory for the private sector, it has proved to be financially worthwhile for commercial organisations to use the same principles.

The following are some initiatives which have acted as drivers for Whole Life Value:

- Achieving Excellence in Construction, Guidance Note 7 on Whole Life Costs (Office of Government Commerce 2000).
- Building a Better Quality of Life (Department of Environment, Transport & the Regions (DETR 2000) - promoting a sustainability agenda.

The Latham report (1994) recommended that clients should seek to evaluate all tenders on the basis of quality, likely cost-in-use, out-turn price and known past performance as well as price. 'Rethinking Construction' (Egan, 1998) promoted the view that construction should be designed and costed as a total package, including costs in use and final decommissioning.

The key methodologies and techniques supporting WLV currently include whole life costing (WLC), life-cycle assessment (LCA), value management (VM), risk management (RM) and multi-criteria assessment (MCA). WLC deals primarily with financial costs, whereas LCA deals primarily with environmental impacts. Individually, WLC and LCA cannot comprehensively cover all financial, environmental, social costs and benefits associated with achieving the best WLV (Mootanah, 2005).

2.2.2 Whole Life Costing

Over the last 30 years there have been many definitions of Life Cycle Costing (LCC), Whole Life Costing (WLC) and Whole Life Cycle Costing (WLCC). (Flanagan *et al.*,1989; Robinson and Kosky, 2000; BMI, 2003; Boussabaine and Kirkham, 2004).

This issue has finally been addressed by ISO 15686-5 (2008).

Figure 2.2 shows the Whole Life Cost (WLC) and Life Cycle Cost (LCC) elements for buildings and constructed assets. It indicates graphically the costs included in Life Cycle Costing, and those normally dealt with as non-construction costs - collectively termed Whole Life Costing.

2.2.1 Life Cycle Costing

The International Standards Organisation (ISO), (2008) defines lifecycle costs as “the cost of an asset throughout its lifecycle while fulfilling the performance requirements”. Life cycle costing is basically a simple concept – it provides answers as to what future costs will be expected when undertaking any building project. So it is only a projection of the costs that result from commissioning a building, and which will be the responsibility of the client. It is not difficult, but it is complex because potentially there are a large number of costs to consider. It is also complicated by the introduction of time into the equation and therefore the ways of how to treat the effects of inflation, and lost investment opportunities or money.

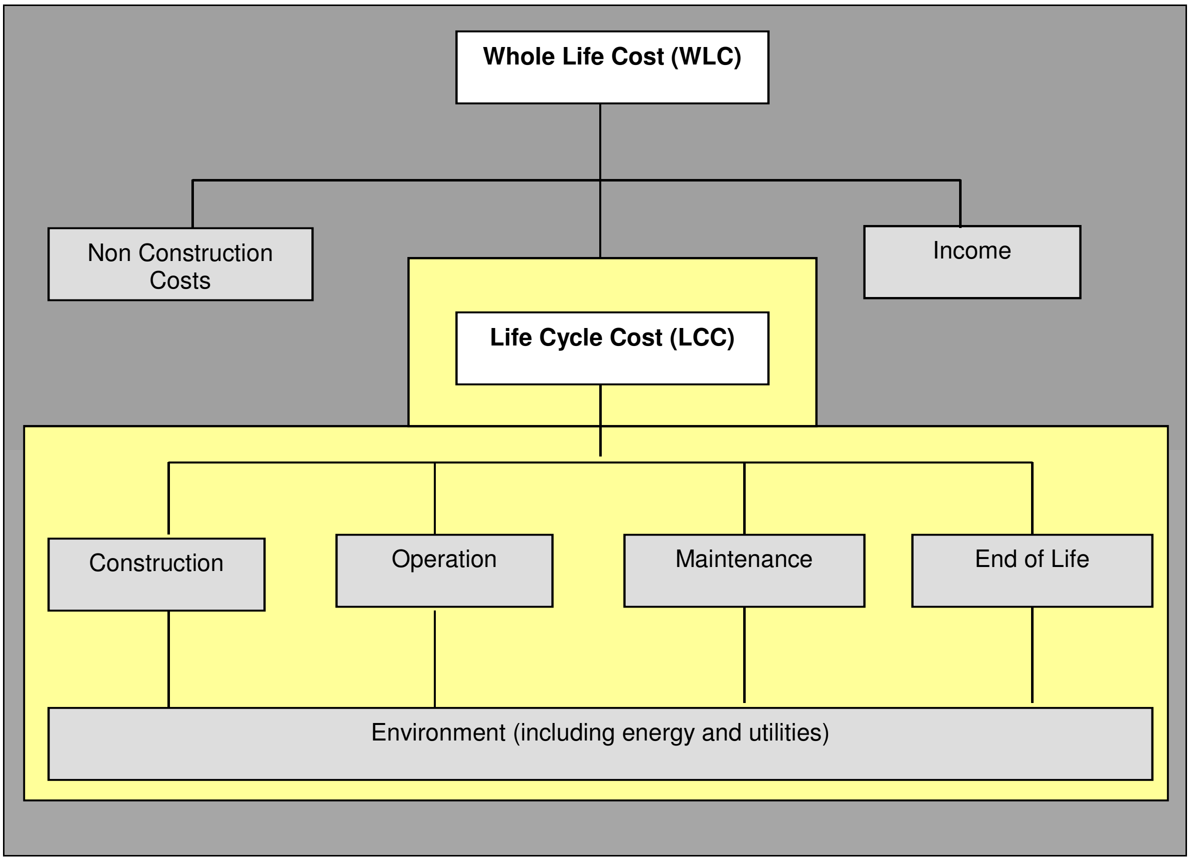

Figure 2:2 Whole Life Cost and Life Cycle Cost elements, for buildings and constructed assets, (ISO 15686-5, 2008)

2.2.2 Phases of Life Cycle Costing

According to ISO 15686-5 (2008), Life Cycle Costing of any constructed facility or building project, consists of four distinct phases:

- Strategic Investment Planning – this may be acquisition by construction, or purchase/leasing;
- Design and Construction – including any fit out/adaptation and commissioning for occupation;

- Operation and Maintenance – including repairs and replacements and energy and environment costs. Renewal and adaptation and
- End of Life/Disposal – which may include demolition/decommissioning and remediation of the site.

Figure 2.3 shows the phases of a built asset Life Cycle Costing.

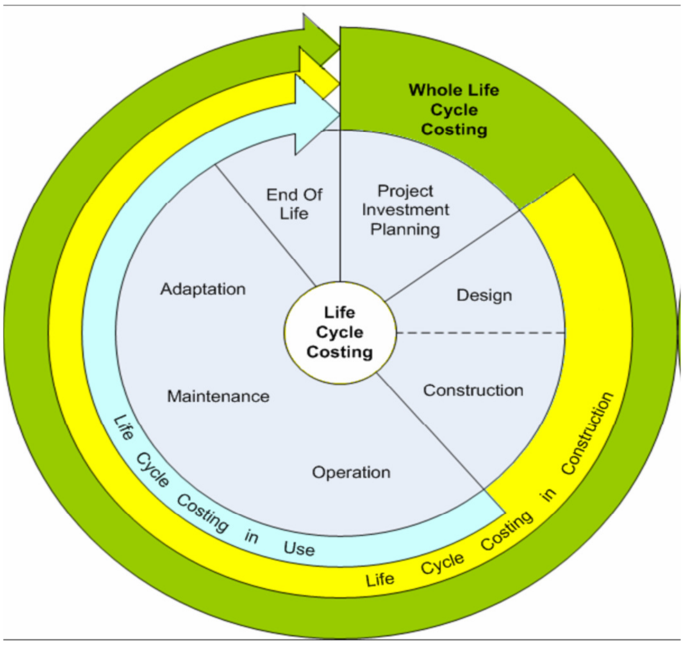

Figure 2:3 Analysis at different stages of the life cycle, ISO 15686-5 (2008)

The literature clearly indicates the importance of carrying out WLC and LCC analysis prior to undertaking any major building project. The results of the analysis will inform clients of the costs the building is likely to incur during its life period, and the design team will be able to produce alternative designs to enable the client to make informed decisions on how they wish to proceed with the project. This research focusses on the operation and maintenance phase, otherwise termed as the ‘Facilities Management’ phase and in particular the maintenance aspect of facilities management.

2.3 Facilities Management

In the 1990s, Facilities Management (FM) emerged as one of the fastest growing sectors in the construction industry. Many organisations identified the need to properly manage complex and expensive support facilities and readily acknowledged the importance of FM. The tasks are multi-disciplinary and cover a wide range of activities, responsibilities, and knowledge, because almost every aspect of an organisation's activities will come under the scope of FM (Reeves, 1999; Kincaid, 1994). The FM sector is now large and complex, comprising a mix of in-house departments, specialist contractors, large multi-service companies, and consortia delivering the full range of design, build, finance and management. Estimates vary; market research suggests that, in the UK alone, the sector is worth between £40bn and £95bn per annum (BIFM, 2014).

The International Facilities Management Association (IFMA) defined FM as "a profession that encompasses multiple disciplines to ensure functionality of the built environment by integrating people, place, process and technology". The British Institute of Facilities Management (BIFM) defined the term Facilities Management as 'the integration of multi-disciplinary activities within the built environment and the management of their impact upon people and the work place.' FM also defined as an integrated approach to maintaining, improving and adopting the buildings of an organisation, at appropriate cost in order to ensure that systems and services support core operations and processes (Barret, 1995; Bernard Williams Associates, 1994; Alexander, 1996).

From the above definitions, it can be seen that the emphasis of facilities management is on the skills for managing the occupancy of a facility and how its use evolves and develops in response to the changing demands of the occupier. Edum-Fotwe *et al.*,

(2003) state "on a day-to-day level, effective FM provides a safe and efficient working environment, which is essential to the performance of any establishment, whatever its size and scope of works".

Building performance is one of the key issues in the context of facility management for contributing to business (Amaratunga *et al,* 2000). There are a number of factors related to building performance, including facility efficiency, hygiene standard, indoor air quality, energy efficiency, lighting standard, thermal comfort, safety and information technology. There are challenges for methods of measuring the performance of buildings (Amaratunga *et al,* 2000). There is a direct link between facility management and performance management. Without understanding this, the performance of buildings cannot be measured and improvement in building performance cannot be identified.

2.4 **Facilities Management Performance Measurement**

The fundamental purpose of performance measurement is to effect control. Control means planning what is required to be done, monitoring what has been achieved and taking action to minimise the variance between the two (Horner, 2006). Organisational control is the process whereby an organisation ensures that it is pursuing strategies and actions which will enable it to achieve its goals. The measurement and evaluation of performance are central to control. Lord Kelvin on why performance should be measured stated 'when you can measure what you are speaking about and express it in numbers, you know something about it'. Horner, (2006) stated that 'what ain't measured ain't managed'. These familiar statements demonstrate the importance of performance measurement.

In the cycle of continuous improvement, performance measurement is required to:

- Identify and track progress against organisational goals
- Identify opportunities for improvement
- Compare performance against internal and external standards

The performance of an organisation should be regularly reviewed to identify its strengths and weaknesses. Within the continuous improvement cycle, measurement of performance plays an important role in quality and productivity improvement activities (DTI, 2005).

With increasing awareness that maintenance creates additional value in the business process, more and more companies are treating maintenance as an integral part of the business process, and the measurement of maintenance performance has become an essential element of strategic thinking of many companies involved in service and manufacturing industry (Kumar, 2006). Kotze and Visser, (2012) state that maintenance performance measurement is “essential to ensure that maintenance objectives are achieved and that maintenance adds value for the company”. Alexander (1996) identified measurement of performance among the essential issues for effective implementation of facilities strategy’. Neely, (1998) on the other hand argued that performance measurement could contribute to more effective control through giving insights as to the nature and levels of control mechanisms to consider.

Many maintenance organisations are striving for ways to improve business performance. Measuring performance is becoming essential for helping organisations to increase competitiveness and profitability. Of more importance is to identify an organisation’s strengths and weaknesses. Arguments exist on the methodology for performance measurement and require identifying performance management strategies to achieve goals and objectives (Coetzee, 1999; Amaratunga and Baldry, 2002). One of the purposes of performance management is to assist top management to identify the trends in the industry and take necessary steps for improving organisational capability (Lee, 2009).

A number of researchers, (Kagioglou *et.al.*, 2001; Amaratunga and Baldry, 2003; Tranfield and Akhlaghi, 1995), have tried to introduce conceptual and/or theoretical frameworks for performance management and measurement in the areas of construction management in general and FM in particular. However, the literature review indicated that little effort has been made to measure performance of building maintenance activities with the ultimate aim of assessing productivity levels.

2.5 Building Maintenance

Maintenance is a set of organised activities that are performed to maintain a component or a system in an acceptable operational condition at a minimum cost. BS 4778 defines maintenance as *the combination of all technical and administrative actions, including supervision actions, intended to retain an item in, or restore it to, a state in which it can perform a required function*. Son and Yuen (1993) asserted that 'retaining an item suggests problems are prevented from occurring by carrying out work before failures develop while the term 'restoring' suggests that smaller defects may be allowed to occur before any corrective action is taken. 'Maintenance activities could be either repair or replacement that are required for a component or a system to reach its expected performance level and these activities should be carried out with a minimum cost. ISO 15686-5 defines maintenance cost as *the total of necessarily incurred labour, material and other related costs incurred to retain a building or its parts in a state in which it can perform its required functions*. Bernard Williams Associates, (1994) and Lee, (2009) argue that the impact of inadequate maintenance of buildings could have serious implications for the value of the asset and the quality of the work environment provided to workers within the organisation. Increased absence through sickness and genuine ill health could be blamed on inadequate maintenance in particular in the case of mechanical and electrical services.

Horner *et al.,* (1997) state that the objectives of building maintenance are to ensure that buildings and their associated services are in a safe condition, are fit for use; that statutory requirements are complied with, and that the value and quality of the building is maintained. Kumar *et al.,* (2000) added the objectives of reducing the consequences of failure, extending the life of the asset and reducing the overall maintenance cost. Other researchers examined other various aspects of building maintenance. Shen and Lo, (1999) presented an analytical approach of optimising resources for building maintenance through the use of a prioritisation model for planned maintenance. El-Haram and Horner, (2002) explored the factors affecting housing maintenance cost. Pitt *et al.*, (2006) examined the technical and management functions in building maintenance. Lee and Scott, (2009) examined the strategic and operational factors influencing the management of building maintenance in sports and leisure facilities.

2.5.1 Maintenance Policy and Strategies

Maintenance policy is described as a written document which provides a management framework to ensure that the building assets are maintained appropriately and to support the organisation's strategic objectives (Lee and Scott, 2009). BSI 8210, (1986) defines maintenance policy as follows: *The maintenance policy should ensure that value for money expended is obtained, in addition to protecting both the asset value and the resource value of the buildings concerned and the owner against breaches of statutory and legal obligations.* RICS (1999) contend that a building maintenance policy should be a clear statement of the objectives and methods to be employed in keeping buildings fit for use and preserving their asset value. It should define the framework on which all building maintenance and management operations are based and state the life expectancy, or required life expectancy, of the asset. RICS (1999) assert that the emphasis of a maintenance policy should be to maximise planned and cyclical maintenance works and reduce responsive maintenance. However, El-Haram and Horner (2002) state that there are several strategies available when maintaining a building. It is possible for example at the design stage, to address the causes of failure in order to reduce the need for maintenance. The maintenance manager may need to decide whether to repair or replace an item, whether to carry out periodic maintenance at fixed intervals, whether to carry out regular inspections, or whether simply to respond to the requests of the users after failure has occurred. Thus, building maintenance can be divided into the following, Kumar *et al* (2000):

1. Failure Based Maintenance, where corrective maintenance tasks are initiated by the occurrence of failure, i.e. loss of function or performance;
2. Time Based Maintenance, where preventive maintenance tasks are performed at predetermined times or corresponding to prescribed criteria and intended to reduce the probability of failure or the performance degradation of an item.
3. Condition Based Maintenance, where conditional maintenance tasks in the form of inspections are performed at fixed intervals of operation, until the performance of a preventive maintenance task is required or until a failure occurs requiring corrective maintenance.

The strategies above may be implemented in total or in part. The resulting maintenance policy can have a significant impact on the operating costs. The policy and its strategies should consider the potential changes to the stock of buildings, and give regard to major refurbishment work. It should also highlight areas where neglect or failure could be positively harmful to vital business (Bernard Williams Associates, 1994).

2.5.2 Optimisation of maintenance strategies

The choice of a maintenance optimisation model or methodology depends on the objectives of optimising the maintenance strategies. In this part of the literature review, the objective is to explore how the number of maintenance tasks and consequently the costs of maintenance can be reduced.

Maintenance optimization models can be both qualitative and quantitative (Dekker, 1996; Al-Najjar and Alsyouf, 2003). Quantitative optimisation models that seek to determine the optimal maintenance interval or the timing of maintenance activity incorporate various deterministic/stochastic models and can be defined as ‘those mathematical models whose aim it is to find the optimum balance between the costs and benefits of maintenance, while taking all kinds of constraints into account’ (Dekker, 1996). Among the earliest maintenance optimisation policies was the age replacement policy which involves replacing an item when it fails or when it reaches a predefined age. This has been applied widely in industry (Van Noortwijk and Fangopol, 2004). Goel and Grossmann (2004) presented the Mixed Integer Linear Programming (MILP) formulation which is a new mathematical model for the integrated design, production and maintenance planning for a multi process plant. Bevilacqua and Braglia (2000) described the application of the Analytical Hierarchy Process (AHP) for the selection of a maintenance strategy in an oil refinery. In an attempt to assess the most popular maintenance strategy, Al-Najjar and Alsyouf (2003) used Fuzzy Inference Theory and Fuzzy Multiple Criteria Decision Making (MCDM) evaluation methodology. Mechefske and Wang (2003) evaluated and selected the optimum maintenance strategy and condition monitoring techniques by utilizing Fuzzy Linguistics. Other researchers have used Simulation and Markovian probabilistic models to determine the optimum maintenance policy and for the modelling of continuously monitored deteriorating systems (Chen and Popova, 2002; Barata *et al*., 2002). These are but a few of many methodologies used in industry as among the problems of maintenance optimisation are the very specific maintenance problems relating to specific industries. This has resulted in a large number of different maintenance optimization models. While quantitative optimization models are useful for many industries in establishing optimum maintenance intervals and duration, they do not however, meet the objective of this part of the study, which is to reduce the number of maintenance tasks.

Application of qualitative maintenance optimization models has the potential of reducing the number of maintenance tasks. These models are concerned with selecting the most applicable and cost effective maintenance strategy (Kumar *et.al*, 2001; Moubray, 1997). They include techniques like whole life costing (WLC), total productive maintenance (TPM), reliability centered maintenance (RCM). The WLC model is a tool to develop key metrics for selecting the most cost effective maintenance strategy (Blanchard, 1998). Maintenance activities are the main contributor to WLC (Marenjak, 2004), accordingly, maintenance optimisation should be considered as an important factor to achieve significant WLC reduction.

Total Productive Maintenance (TPM) (Dekker, 1996; Al-Najjar and Alsyouf, 2003; Garg and Deshmukh, 2006) is a maintenance philosophy that requires the total participation of the work force. TPM incorporates the skills and availability of all employees with the objective of improving the overall effectiveness of the asset (Hartmann, 1992; Naylor, 1996; Davis, 1997). Effectiveness is improved by eliminating wastage of time and resources (Hartmann, 1992). Davis, (1997) states that for successful implementation of TPM, total workforce participation is required, including everyone from top-level management to maintenance personnel. Without this cooperation it is likely that an implementation of TPM method will fail. Typically, total productive maintenance is a concept that is most easily applied to a manufacturing facility.

Reliability centered maintenance (RCM) is another method that is implemented to optimize the maintenance strategy of an asset/system. The final result of an RCM program is the implementation of a specific maintenance strategy on each of the elements of a system. The maintenance strategies are optimized so that the reliability and the service life of the system/element is maintained using cost-effective maintenance techniques (Moubray, 1997; Kumar et. al, 2000). RCM offers a systematic and efficient decision support system tool for the optimisation of plant and equipment maintenance (Bertolini and Beilacqua, 2006). In particular the RCM approach is designed to minimise maintenance costs by balancing the costs of different maintenance strategies.

Garg and Deshmukh, (2006) contend that despite the increased interest within industrial production systems in the topic of maintenance optimisation models, the application of these models has had limited impact on decision making within maintenance organisations. Dekker (1996) argues that mathematical analysis and techniques have been the focus of many academic studies, rather than developing solutions for real maintenance problems. Another observation is that despite the development of many optimisation models, it seems that these models were developed to address a particular problem within a particular industry. There is therefore, little guidance on which models are suitable for which practical problems. There is no general model covering all possible technical systems or the various modes of deterioration (Dekker, 1996; Garg and Deshmukh, 2006). A sample of maintenance optimisation models is highlighted in Table 2:1. As indicated previously, the objective of optimising maintenance strategies here is to reduce the number of maintenance tasks and the costs of maintenance. Use of quantitative optimisation models does not assist in achieving this objective.

Table 2:1 A sample of maintenance optimisation models

Qualitative Approaches		**Quantitative Approaches**	
Model	Application	Model	Application
Mixed Integer Linear Programming (MILP)	Mathematical model for integrated design, production and maintenance planning for multi process plant	Whole Life Costing (WLC)	Ensuring cost effective maintenance strategy to achieve WLC reduction through consideration of asset maintenance through all stages of its life cycle.
Analytical Hierarchy Process (AHP)	Selection of best maintenance strategy of critical centrifugal pumps for oil refinery involving goal and linear programming.	Total Productive Maintenance (TPM)	To improve the overall effectiveness of the asset by eliminating wastage of time and resources. This involves the active participation of entire workforce to succeed.
Fuzzy Multiple Criteria Decision Making (MCDM)	Selecting best maintenance strategy in manufacturing using judgement of decision makers translated into fuzzy numbers.	Integrated Logistics Support (ILS)	An approach used to influence the support of an asset in order that it can be supported at a minimum cost during the utilisation phase of the asset life cycle.
Simulation and Markovian probabilistic models	Mont Carlo simulation to determine optimum maintenance policy for modelling continuously deteriorating monitored systems.		

PART 1 - ROLE OF INTEGRATED LOGISTICS SUPPORT IN OPTIMISING MAINTENANCE STRATEGY

2.6 Integrated Logistics Support (ILS)

Qualitative optimisation models, in particular RCM are concerned with selecting the most appropriate and cost effective maintenance strategy. Within maintenance optimisation, RCM as part of Integrated Logistics Support (ILS) has been credited with reducing maintenance and logistics support costs for an asset by up to 50% (Tysseland, 2008). Integrated logistic support is viewed as a management technique to ensure that the installed asset meets the expectations of the clients during the life cycle of the asset. This achievement is not only related to operational efficiency, but also related to cost effectiveness concerns (Blanchard, 2004). Therefore, maintenance-related solutions, e.g. maintenance optimisation, should be approached from a whole life cycle and logistic perspective.

ILS has been applied in many industries to optimise maintenance strategies and to support activities leading to high equipment availability and maintainability (Bouachera *et. al*, 2007).

The defence industry demonstrated that the costs of a project can be significantly reduced over the life of an asset by using integrated logistics support (ILS). Application of RCM methodology in the Royal Navy indicated a reduction of 19% in WLC on a pilot study of 12 ships, over 8.5 years. Application of ILS to US Navy radar systems has increased availability from 79.5% - 90.5%. Similarly, Booz Allen consultants used ILS methods to help Johnson and Johnson decrease critical clinical trial cycle times by 50% and to help Bank of America reduce ATM withdrawal losses by 30%. www.boozallen.com/media/file/logistics-engineering-perspective-vp.pdf. Within the construction industry, El-Haram and Horner (2003) have reported cost savings of 18% when ILS techniques were applied in the case of existing buildings.

2.6.1 Definitions of Integrated Logistic Support (ILS)

There have been many academic publications on ILS and interrelated engineering fields of reliability and maintenance that indicate the increased interest in the field and the important part ILS plays in asset management. (Johns, 1987; Ebeling, 1996; Blanchard, 1992; Kumar *et al*, 2000). There is an increased interest in approaches which make it possible to maximise the output of a system and to minimise its whole life cost.

ILS was developed by the US Department of Defence in the early 1980s. It encompasses the various technical and logistic disciplines to achieve maximum operational availability. “It is a management and technical approach used to influence the support of a designed system in order that the system can be supported at a minimum cost during the utilisation phase of the systems’ life cycle” (Blanchard, 1998).

Green (1991) described ILS as “an engineering and management tool that helps to ensure that the customer or the user will receive a project that will not only meet performance requirements such as durability, reliability, maintainability, quality and availability, but one that can be expeditiously and economically supported throughout its life cycle”. ILS techniques such as Failure Modes and Effects Analysis, RCM, Level of Repair Analysis, Availability, Reliability and Maintainability etc. have been developed by the defence and aircraft industries as tools to acquire a system which achieves the best balance between WLC, performance, supportability and operational availability (Kumar *et al.*, 2000). These techniques are embodied in MIL.STD-1388 (US Department of Defence, 1983) and the UK DEF-STAN 00-60 (UK Department of Defence, 1996). The techniques can be used both at the design stage and throughout the life cycle of a project. Following successful application in the defence and aerospace industries, its use has been adopted by a number of other sectors including power generation, petrochemicals, and manufacturing. According to The US Department of Defence (1983), the primary aim of the ILS process is to influence the design of a facility, ensuring that all elements of design are fully integrated to meet the client requirements and the facility's operational, maintenance, support and safety needs at a minimum whole life cost. Although ILS is intended for use at the design stage, it has been applied in the construction industry for the maintenance of existing building stock. The ultimate objectives of ILS are as follows (El-Haram and Horner, 2003):

- influence project design from the operation, maintenance and support point of view;
- integrate the ILS elements;
- identify, develop and schedule the necessary support resources;
- achieve high operational availability levels at lowest life cycle cost;
- determine ILS elements and perform trade-offs amongst them;
- perform design trade-offs to optimize operation, maintenance, support and economic issues;

2.6.2 Integrated Logistics Support and the Construction Industry

Whilst ILS was developed primarily for use within the defence industry, it has become widely used within a number of other industries. The Nuclear Power Industry, Aerospace, Petrochemical, Power generation, Shipping and the Construction Industry have all adopted ILS techniques to assure systems' availability and performance requirements.

ILS means achieving an acceptable balance between whole life cost, performance and operational availability (UK MOD, 1996). In other words a building (building fabric and service equipment elements) should be designed so that it is able to perform all the tasks required of it, at a minimum whole life cost, and so that it will always be available when required. ILS helps to ensure that a building is conceived, designed constructed, maintained and operated to be functionally effective from the beginning to the end of the whole life of the building, including its disposal (Kumar *et al*., 2000).

Within the construction industry, research conducted at the Bartlett College (Young *et al*, 1996) sought to compare refurbishment in the shipping and construction industries and a number of similarities and transferable techniques that are of benefit for both industries were identified. This study however, focused on the possibility of transferring ILS from defence to the construction industry and did not specifically consider whole life costs (Bartlett and Clift, 1999). Research at the University of Reading proposed a system using ILS within a Through Life Business Model (TLBM) which was developed specifically for the building services sector in order to reduce or eliminate deficiencies experienced from inadequate design and planning processes while taking into consideration operation and maintenance issues. This concept which is based on the effective integration of not only the construction process, but also the concepts, tools, techniques and technologies that can bring about this integration (John *et al*.2005). ILS is a holistic approach that also includes human resource management and information technology. El-Haram and Horner (2003) applied ILS techniques to the development of cost effective maintenance strategies for existing housing building stock. There were no examples in the literature of applying ILS techniques to investigate maintenance strategies for a single building system or component.

2.6.3 Description of ILS techniques

The application of ILS involves the implementation of various techniques such as Reliability Analysis (RA), Maintainability Analysis (MA), Supportability Analysis (SA), Availability Analysis (AA), Fault Tree Analysis (FTA), Level of Repair Analysis (LORA), Failure Mode Effects and Criticality Analysis (FMECA) and Reliability Centred Maintenance (RCM). According to Smith, (1993) and Kumar *et. al*, (2000) these are used to:

- develop and evaluate alternative support concepts;
- determine asset/system logistic support requirements;
- perform design trade-offs to optimise logistic supportability;
- perform trade-offs among ILS elements;
- provide input to system design;
- measure the impact of WLC on support system alternatives

The application of ILS techniques will generate technical and economic data and information to be used to integrate the selected technique(s) to produce an asset that will be technically and economically viable throughout its lifetime (Kumar *et.al*, 2000). Their application differs from project to project and from phase to phase; they should be modified to suit the specific life cycle phase. ILS techniques are summarised in Table 2:2. It is imperative that a maintenance strategy is matched to a failure mode and its criticality and for this reason, tools such as FMEA, FMECA and RCM as well as analysis of historical data should be used. Once failure modes are understood, selecting the appropriate maintenance strategy becomes a simpler decision.

Table 2:2 Summary of ILS Techniques

No	ILS Technique	Application
1	Reliability Analysis (RA)	Is defined as the probability that a component or system will perform a required function in a satisfactory manner for a given period under stated operating conditions (Ebeling, 1997). It is of particular relevance during early design stages to determine the WLC of an asset once it becomes operational.
2	Maintainability Analysis (MA)	Maintainability is expressed in terms of maintenance frequency, maintenance elapsed time and maintenance cost (Kumar et. al, 2000). It is the ability of an asset to be maintained when maintenance is performed according to specified procedures and it requires specific design features for its implementation.
3	Supportability Analysis (SA)	Is concerned with designing an asset and/or system which can be supported throughout the life cycle at a minimum WLC (Kumar et. al., 2000). It involves the determination of facilities, equipment and resources for an asset to be supported in a cost effective way.
4	Availability Analysis (AA)	It encompasses reliability, maintainability and supportability to ensure an asset is performing its stated function at a given point in time when used under stated operating conditions.
5	Fault Tree Analysis (FTA)	Usually used during early design stages to gain an insight into the critical aspects of an asset through a top-down approach to identifying failures and all the possible causes and origins of that failure.
6	Level of Repair Analysis (LORA)	Is an analytical process to evaluate the cost of alternative maintenance options by examining manpower costs, support equipment and spare parts (Blanchard, 1998).
7	Failure Mode and Effects Analysis (FMEA)	Is a systematic approach to identify all possible ways in which failure of an asset can occur together with its causes and thus the failure's potential effect on the asset (Kumar et al, 1990).
8	Reliability Centred Maintenance (RCM)	Is designed to minimise maintenance costs by balancing the costs of different maintenance strategies by utilising an efficient decision support system tool.

2.6.4 Failure Modes and Effects Analysis (FMEA)

Failure Modes and Effects Analysis (FMEA) is a systematic approach to identify all possible ways in which failure of a system (element, service or piece of equipment) can occur together with its causes and the failure's potential effect on the system (Kumar *et al*., 1990). The FMEA method is a qualitative assessment of risk, predominantly relying on the judgment of experts (Moubray, 1997). It is a method of reliability analysis for the purpose of identifying failures that may affect system function and to inform the setting of action priorities (BS5760, 2009). When FMEA is extended to include an assessment of the criticality of failure, or how severe is the failure effect and the probability of occurrence, the process becomes known as FMECA, Failure Mode Effects and Criticality Analysis.

FMEA and FMECA are important techniques for a reliability assurance programme. They can be applied to a wide range of problems which may occur in a technical system, and can be carried out in varying degrees of depth, or modified, to suit a particular purpose. The objectives of FMEA are (BS 5760: Part 5: 1991):

- A comprehensive identification and evaluation of all the unwanted effects within the defined boundaries of the system being analysed.
- Classification of identified failure modes according to relevant characteristics

FMEA is therefore an integral part of the ILS process, planning the corrective and preventive actions through the use of failure analysis (Marenjak, 2004). The output data of FMEA analysis is a list of all possible failure modes, causes, and effects of each failure mode, list of critical elements as well as a list of elements which require design improvement. This is then used as the input data for a Reliability Centred Maintenance analysis and for future development of the maintenance strategy and whole life costs (Marenjak, 2004), Figure 2.4.

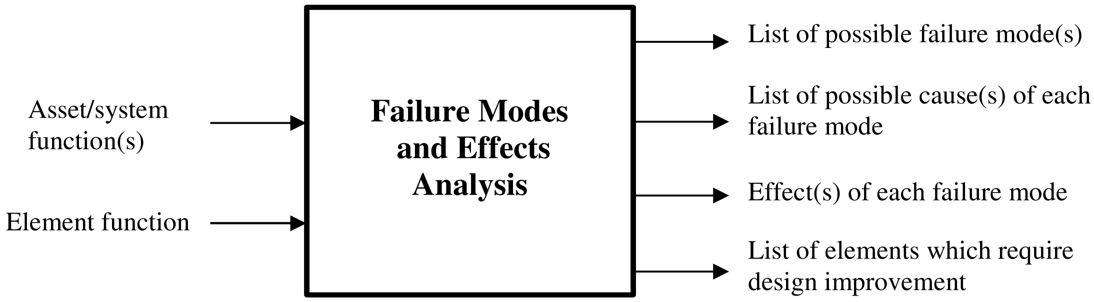

Figure 2:4 Data inputs and outputs of FMEA (Marenjak, 2004)

2.6.5 Reliability Centred Maintenance (RCM)

The Reliability Centred Maintenance concept originated within the aircraft industry. Nowlan and Heap from United Airlines defined a general approach to the design of maintenance programmes. Their approach led to the development of a maintenance process based on system functions, consequences of failure and failure modes. Their pioneering work led to the development of Reliability Centred Maintenance, which was first published in 1978. Afefy (2010) contends that the main objective of RCM is the cost effective maintenance of a system/element's inherent reliability. Kumar *et.al* (2000), while including this objective among the objectives of RCM, state that the main objective of RCM is to preserve system functions given due consideration to the objectives of maintenance including reducing costs, achieving environmental and safety targets and meeting operational goals. There are several definitions of RCM depending on the type of industry applying the technique. Rausand, (1998) defined RCM as a technique for developing a preventive maintenance programme and has adopted the definition offered by the Electric Power Research Institute (EPRI), that is "RCM is a systematic consideration of system functions, the way functions can fail, and a priority-based consideration of safety and economics that identifies applicable and effective maintenance tasks". El-Haram and Horner (2003) defined RCM as "a systematic approach for identifying the most applicable and cost effective maintenance regime for a building in accordance with a specified set of procedures". NASA, (2008), stated that RCM integrates preventive maintenance (PM), predictive testing and inspection (PT&I), reactive maintenance and proactive maintenance to increase the probability that a machine or component will function in the required manner over its design life cycle with a minimum amount of maintenance and down time. RCM has now been applied successfully within other industries, such as the military forces, the nuclear power industry, the oil and gas offshore industry and to a limited degree, the construction industry. Figure 2.5 shows data inputs and outputs of the RCM process.

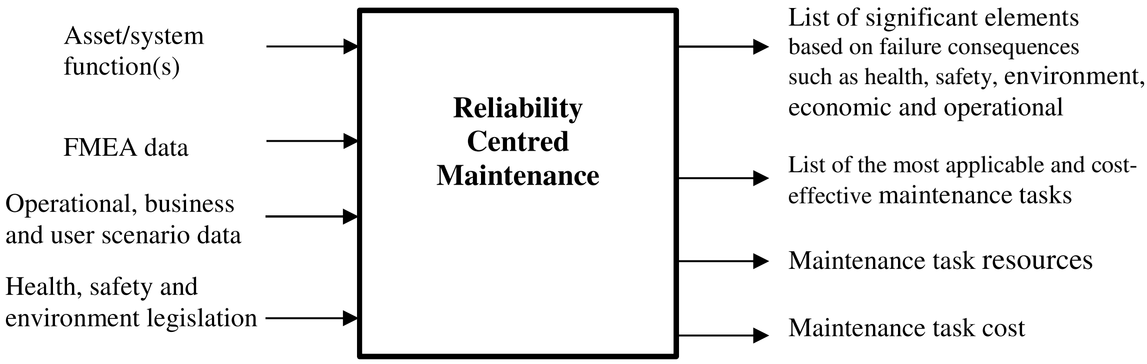

Figure 2:5 Data inputs and outputs of RCM Process (Marenjak, 2004)

To be able to determine the effects and consequences of failure and to determine the most appropriate mitigating task, an understanding of the meaning of failure is essential. Moubray (1991) defined failure as the inability of any physical asset to meet a desired standard of performance. El-Haram (1995) contends that failure can be defined in three ways:

- An element has suddenly become completely inoperable and can no longer perform its required function(s);

- An element is still operable but incapable of fulfilling some or all of its intended functions at the level of performance originally specified;
- An element has gradually deteriorated to an unsatisfactory level of performance or condition, and its continued operation is unsafe, uneconomical or aesthetically unacceptable.

Moubray (1991) divided failures into two categories:

- Evident failures are those failures that under normal circumstances, the user will discover as and when they occur;
- Hidden failures are those failures in which the user will not be aware of the loss of function under normal circumstances.

2.6.6 Maintenance tasks

Maintenance tasks that may results from an RCM analysis include the following:

2.6.6.1 *Failure-based maintenance*

This is a reactive maintenance task that is performed on an item or element that has ceased to meet an acceptable level of operational requirements (Kumar *et al*., 2000). According to this type of maintenance task any element in a building is used until it fails. It encompasses all activities, including repair or replacement of an element that has failed to perform its required function (Pitt *et al*., 2006). It is sometimes referred to as responsive, corrective maintenance or day-to-day repair. A failure-based maintenance task is not implemented until after the failure has occurred. These tasks are more appropriate and cost effective for failures with no health, safety, economic or operational consequences. For failure modes with appearance consequences, no pre-determined action is taken to prevent failure unless the cost of failure is greater than the actual cost of repair (El-Haram and Horner, 2003). The way to perform corrective maintenance activities will involve conducting steps relating to fault detection, fault isolation, fault elimination and verification of fault elimination (Knezevic, 1997). Despite the ease of this type of maintenance and that building elements will continue to perform their functions under normal working conditions, it does however, have some disadvantages. Among these disadvantages, according to Kumar *et al*., (2000) are the following:

- Element failure may occur at times that are not convenient
- Inability to adequately plan maintenance activities
- Consequential damage to other items in the system may be caused as a result of the failure.

Because of these limitations, organisations and maintenance managers are continuously looking to apply more effective and reliable maintenance strategies.

2.6.6.2 ***Condition-based maintenance (CBM)***

Condition-based maintenance is defined as that carried out in response to and as a direct result of a major deterioration or change in a unit as possibly indicated by a change in monitored performance (Pitt *et al*, 2006). The concept of CBM acknowledges that the principal reason for carrying out maintenance is a significant deterioration in the performance and/or condition of the element (El-Haram and Horner, 2003). Therefore, the ideal time to perform maintenance is determined from a condition survey used to determine the actual state of each constituent item in a building. The implementation of a preventive maintenance task should be based on the actual condition of the element or system (Knezevic, 1997).

El-Haram and Horner, (2003) concluded that CBM is the appropriate maintenance strategy for elements whose condition and performance can be appropriately monitored. For failure modes that have health and safety consequences, the maintenance task must result in a reduction of the risk of failure in order for the building to be safely used. For failure modes that have economic and operational consequences the cost of monitoring the condition must be lower than the cost of repairing the failure using alternative maintenance strategies. For failure modes that have appearance consequences, the cost of inspection must be lower than the cost of doing nothing (Kumar *et al.*, 2000).

2.6.6.3 ***Time-based maintenance (TBM)***

TBM is a preventive maintenance task that is carried out at predetermined intervals in order to reduce the probability of failure and/or improve the operational performance (Knezevic, 1997, Kumar *et al.*, 2000, Wang *et al.*, 2007). The term 'time' may refer to a specified period of time, operating time or age and the aim is to carry out a scheduled maintenance task to ensure that an element/system continues to perform its function satisfactorily before failure occurs. Among the benefits of implementing TBM policy is the ability to plan the maintenance work in advance ensuring that all maintenance resources are available for the maintenance task to be performed (Kumar *et al.*, 2000). However, among its disadvantages is that repairs and replacements are carried out unnecessarily as the element/system continues to perform it function (Wang *et al.*, 2007). In an RCM analysis, to implement TBM for failure modes with economic and operational consequences, the cost of carrying out the task or tasks must be less than the cost of the failure prevented, and less than the cost of any other maintenance strategy. For health and safety consequences predetermined repairs and replacements must reduce the risk of failure to ensure the safe use of the element/system (El-Haram and Horner, 2003; Kumar *et al.*, 2000).

2.6.6.4 ***Re-design***

In cases where no applicable and cost effective maintenance task can be identified, re-design becomes necessary. For failure modes with economic consequences, a design change may be appropriate to reduce the economic losses. For failure modes with health and safety consequences, a design change is required to eliminate the failure mode. If the design change is needed for reasons other than health and safety, a cost and benefit analysis is required in order to determine the expected cost saving (El-Haram and Horner, 2003; Kumar *et al*., 2000).

2.6.6.5 ***Failure finding task***

This is a task performed to locate hidden failures which cannot be detected otherwise. Its purpose is to prevent or at least reduce the risk of the associated secondary failure. It is an inspection of a hidden function to identify any potential failure. A failure finding task is applicable to items which are subject to a functional failure that is not evident to the user (Kumar *et al*., 2000).

In general any type of maintenance task - be it reactive, condition-based or time-based, could be applied to every failure in the system. However, only one task or combination of tasks will be the most suitable and cost effective to reduce or avoid the probability of occurrence of unacceptable failures.

2.6.7 Determining ILS elements

An important part of ILS implementation is to identify and determine the various ILS elements. These are the activities and resources required to carry out the selected maintenance task. The logistics support elements indicated in Figure 2.6 used by Marenjak, 2004 may not cover all the support aspects for any given project. To ensure the cost effective application of ILS, both the scope and depth of these elements need to be tailored to meet the specific requirements of each project. This can mean disregarding some elements, with justification, or adding in supplementary elements (Blanchard, 1998; Kumar et. al, 2000; El-Haram and Horner, 2003).

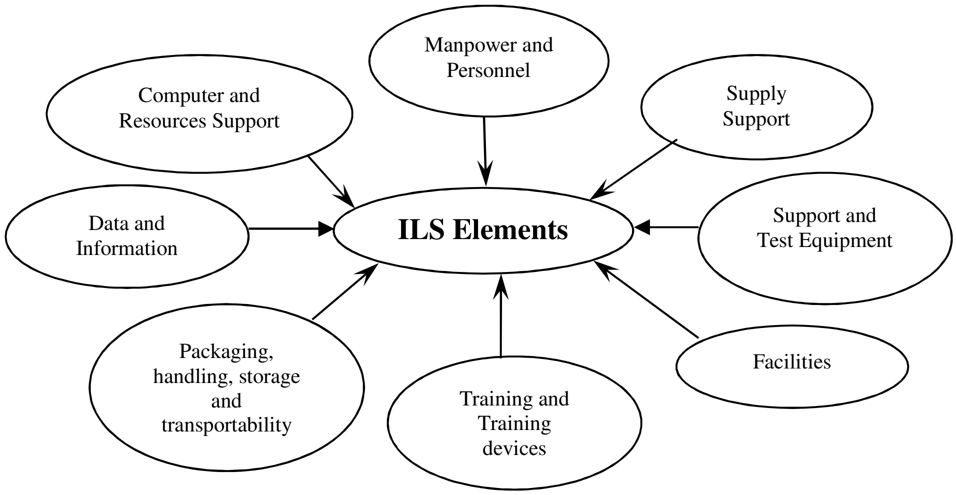

Figure 2.6 ILS elements supporting maintenance tasks (Marenjak, 2004)

El-Haram and Horner (2003) described the ILS elements as follows:

Manpower – This element involves the identification and acquisition of maintenance and support role personnel with the appropriate skills to maintain the building over its lifetime. There must be sufficient manpower, properly managed to handle the maintenance workload.

Supply Support - This includes all management procedures and techniques used to determine the necessary quantities of spare parts, materials, consumables and support procedures. This element requires a cost effective stores and supply support management system to address order administration, pricing and invoicing requirements.

Support and test equipment – This element ensures that the required support and test equipment is available at the time when it is needed to support the maintenance activities. This element includes a determination of what is required, the quantity required and when it is required.

Training – Training includes the process, procedures and techniques used to train personnel to administer, manage and maintain the building or system throughout its life cycle.

Data and Information – The effective and efficient implementation of maintenance strategies requires a comprehensive set of technical data and information. This may include drawings, operational and maintenance instructions, inspection and test procedures, technical manuals, spare/repair parts lists and special tools lists. The management of such a large amount of data and information requires a cost effective approach to data management.

Computer resources support - This ILS element refers to all computers and accessories, software, and databases to support maintenance and operational activities. Computerised maintenance systems provide IT solutions which integrate the support elements listed above.

Facilities – The permanent or semi-permanent real property assets required to support the material system. Facilities management includes conducting studies to define types of facilities or facility improvements, locations, space needs, environmental requirements and equipment (Department of Defence, USA, 1983).

Packaging, Handling, Storage, and Transportation – The resources, processes, procedures, design considerations, and methods to ensure that all system, equipment, and support items are preserved, packaged, handled, and transported properly. This includes environmental considerations and equipment preservation requirements for short and long term storage and transportability (Department of Defence, USA, 1983).

In summary, the review of ILS techniques indicated that most of the techniques are best utilised during the design stages. While some of the techniques such as FTA and LORA may be applied to maintenance problems during the operational stage, their usefulness to fulfil the objective of this part of the study is limited. The review has identified two techniques that could be applied in order to reduce the number of maintenance tasks and their associated costs. These techniques are FMEA and RCM. FMEA is concerned with identifying the occurrence of failures and their potential effects and RCM is concerned with deriving a cost effective maintenance approach.

PART 2 - BUILDING MAINTENANCE LABOUR PRODUCTIVITY

2.7 Productivity Definitions

According to HM Treasury, (2001) productivity is the main determinant of living standards. Raising productivity is the key to raising long-term prosperity. Productivity is a commonly used term that is defined in many different ways. Handa and Abdalla (1989) suggested that the simplest definition of productivity is the ratio of outputs of goods and/or services to inputs of basic resources, e.g. labour, capital, technology, materials and energy. It is calculated as a ratio of the quantity of outputs produced to some measure of the quantity of inputs used. Productivity can also be defined as the relationship between results and the time it takes to accomplish them. Time is often a good denominator since it is a universal measurement and it is beyond human control. The less time it takes to achieve the desired result the more productive the system. Eatwell *et.al,* (1991) defined productivity as a ratio of some measure of output to some index of input use. In other words, productivity is simply the arithmetic ratio between the amount produced and the amount of any resources used in the course of its production. Overall, productivity could be defined as the ratio of outputs to inputs

$$\boldsymbol{Productivity} = \frac{\boldsymbol{Output}}{\boldsymbol{Input}} \qquad (1)$$

Where, outputs could be in units or monetary value of product or service, revenue generated or value added. Input could be in units relating to cost of labour, equipment, materials, capital, so it is very important to specify the inputs and outputs to be measured when calculating productivity.

Productivity is usually regarded as a measure of an organisation's efficiency and can be measured at the national, organisational, project or the task level. Productivity measured at the national or macro level is used to make international comparisons and to track national industrial trends, whilst productivity at the task or micro level is used to inform management decisions. At the organisation level or the project level productivity may be measured to compare either inter- or intra- organisational performance. Horner, (2006) state that productivity is important as it is the common link between cost and time and that its improvement is key to improving performance. Drewin (1982), however, suggests that productivity is not the same as performance. Many workers perform strenuously but have a low productivity due to ineffective work methods. The productivity may be high, however, with low performance, due to use of automatic machinery, which controls the work. Quite often productivity is measured and identified as labour productivity. This fact implies that industries characterised as labour intensive may not be treated equally in relation to less labour intensive industries (Pekuri, *et al.*, 2011).

2.7.1 Partial factor productivity

Partial factor productivity is the ratio of output to one type of input. For example, labour productivity (the ratio of output to labour input) is a partial productivity measure. Similarly, capital productivity (the ratio of output to capital input) and material productivity (the ratio of output to materials input) are other examples of partial productivity.

$$\boldsymbol{Labour\ Productivity} = \frac{\boldsymbol{Value\ Output}}{\boldsymbol{Labour\ Input}} \qquad (2)$$

$$\boldsymbol{Material\ Productivity} = \frac{\boldsymbol{Value\ Output}}{\boldsymbol{Material\ Input}} \qquad (3)$$

$$\boldsymbol{Capital\ Productivity} = \frac{\boldsymbol{Value\ Output}}{\boldsymbol{Capital\ Input}} \qquad (4)$$

$$\boldsymbol{Energy\ Productivity} = \frac{\boldsymbol{Value\ Output}}{\boldsymbol{Energy\ Input}} \qquad (5)$$

Partial productivity measures are easy to understand, easy to obtain data for, and easy to use to compute productivity indices. They are thus widely used and industry wide data are available, but, they can be misleading when used in isolation.

2.7.2 Total Factor Productivity

Total Factor Productivity is the ratio of total output to the sum of all input factors (Sumanth, 1998). Thus, a total productivity measure reflects the joint impact of all inputs in producing the output. In all the above definitions, both output and input(s) are expressed in 'real' or 'physical' terms being reduced to constant monetary currency of a reference period (referred to as base period).

$$\boldsymbol{Total\ FactorProductivity} = \frac{\boldsymbol{Total\ Output}}{\boldsymbol{Labour+Material+Energy+Capital}} \tag{6}$$

Total factor productivity has the advantage of considering all inputs although quantification of these remains a major disadvantage of this measure which makes it impractical. Some of these measures may use different values in different situations depending on the purpose of the analysis, type of process, and ease with which data and information can be obtained.

2.7.3 Total productivity

Total productivity is the ratio of net output to the sum of associated labour and capital inputs (Sumanth, 1998). Net output is the total output minus the intermediate goods and services purchased. In this case, the denominator of this ratio is made up of labour and capital input factors.

$$\boldsymbol{Total\ \ Productivity} = \frac{\boldsymbol{Total\ Output}}{\boldsymbol{Labour\ Input+Capital\ Input}} \tag{7}$$

Total productivity, has the advantage that data is available mainly at corporate level and is easy to compute. However, as the factor does not capture all inputs, a full picture is still lacking leading to the possibility of misguided decision making. The value added approach to defining output is not common at corporate or project level.

2.7.4 Crew level productivity

The definition of productivity at the crew level takes into consideration output in individual activities. Thomas (1992) defined it as the ratio of labour-hours to the quantity of work in place i.e. input/output. For example, masonry wall productivity would be expressed in terms of the number of labour hours required per square metre. This method of measurement is used in construction as the output is normally well defined in contract documents and the problem is actually in determining the labour resources consumed. In the UK and elsewhere, a more common measure of productivity is the ratio of quantity of work in place to the labour-hours expended i.e. output/input. Thus:

$$\textbf{Labour productivity} = \frac{\textbf{Quantity of work}}{\textit{\textbf{Labour hours}}} \qquad (8)$$

Even at this level, productivity definitions differ depending on the purpose. According to Thomas *et al*. (1990) there is considerable difference of interest in the type of labour productivity required for different groups at different times. Horner and Talhouni (1990) differentiate between productivity calculated on the basis of total or paid time; available time; and productive time. This definition of labour productivity could be important for researchers as it offers an opportunity to examine productivity over a relatively short period of time when particular sets of conditions exist. This can lead to the identification of the causes and magnitude of productivity changes.

2.8 **Construction Productivity**

A great deal of research has been conducted examining various aspects of productivity within the construction industry. Shaddad and Pilcher, (1984) proposed a causal model to illustrate the role of management activities on influencing construction productivity. Thomas and Yakumis, (1987) proposed a factor model to identify the factors impacting construction labour productivity. Chan, (2002) explored site management personal perspectives on labour productivity and attempted to illicit key factors leading to improvement. Song and AbouRizk, (2008) presented a model for collecting and measuring labour productivity using historical data applied to steel drafting and fabrication productivities. Dai, *et.al*, (2009) conducted a survey aimed at quantifying craft workers perceptions on the factors affecting their productivity. Previously, (2007), the same researchers carried out an analysis of craft workers and foremen's perceptions of the factors affecting construction labour productivity. Yakubu and Sun, (2010) attempted to identify the causes of cost and time over runs in construction projects and explore inhibiting factors and mitigating measures. There has also been great deal of research at the CMRU at the University of Dundee in the area of productivity management, (Saket, 1986; Noor, 1992; Al–Hajj, 1991; Whitehead, 1990; Talhouni, 1990; Marenjak, 2004 and others). Other research in the area of construction management includes, (Alinaitwe, *et al*, 2007; Soham and Rajiv, 2013; Kagioglou *et al*, 2001; Soekiman, et al, 2011; Nasirzadeh and Nojedehi, 2013).

The Egan Report (1998) indicated that construction in the UK is one of the pillars of the domestic economy. The literature shows that due to the size of the construction industry in the UK, any productivity changes within the sector will have significant direct effects on the national productivity and economic wellbeing of the UK (HM Treasury, 2001; Office of National Statistics, 2014; Horner and Duff, 2001). Productivity in construction is often broadly defined as output per labour hour. This measure of productivity takes into account only one factor of input (i. e. labour) which means that it is a partial or single factor productivity measure. Since labour constitutes a large part of the construction cost and the quantity of labour hours in performing a task in construction is more susceptible to the influence of management than are materials or capital, labour productivity is a major focus of attention. Hass *et.al,* (1999) state that labour productivity is of central importance to the economic health of any nation's economy. Ireland (1992) however, argues that since the capacity to produce is a combination of several factors or inputs, focusing on labour productivity only can be misleading because a number of other factors such as managerial efficiency, economies of scale, use of plant and equipment, and the introduction of new technologies affect the output per unit labour. This view is shared by Hannula, (2002) who argues that although partial productivity ratios are widely used in industry, they are too narrow to give a comprehensive picture of the productivity improvement at the business unit level. There are a number of advantages however for using partial productivity. Focusing on a single factor, in this research, labour, makes the measurement process easier and more controllable and will lead to obtaining more reliable and accurate data. The complex nature of the construction process and the interaction of its activities make the partial factor productivity measure the popular option because effective control systems monitor each input separately (Jarkas and Bitar, 2012). Moreover, since the construction industry employ a large number of operatives, it can be argued that labour is the dominant productive resource, thus construction productivity is mainly dependent on human effort and performance (Jarkas, 2010). The importance of labour productivity was stressed by Horner and Duff, (2001) who suggested that it should be the obvious starting point for any productivity improvement programme. In their examination of construction sites they found that labour costs, material costs and fixed time-related costs including plant, are of similar magnitude on a typical project. However, they argue, that the difference between labour costs on the best and worst construction sites examined is up to 5 times greater than any of the other costs. The emphasis on labour derives from several reasons:

- labour is the most important factor and most easily quantifiable;
- it is the principal productivity factor over which site management has control;
- labour is a resource which can appreciably be influenced by the quality of management; and
- labour productivity is a key potential issue of contention between management and employees as regards performance, and both parties are normally well equipped with relevant data.

These views have been echoed by a number of researchers and labour productivity has been widely accepted as a performance measure in the construction industry (Lowe 1987; Handa & Abdalla 1989; Olomolaiye and Ogunlana 1989; Emsley *et al*., 1990; Horner and Duff 2001).

2.9 **Factors influencing construction labour productivity**

Identifying the factors that impact construction labour productivity is not new. There have been many efforts to identify and classify the factors that influence construction productivity, with a few attempting to establish the relative importance of the individual factors. The factors influencing construction labour productivity were identified from various perspectives. Paulson (1975) identified productivity influencing factors in relation to the cost of labour. Allen (1985) identified the level of skill of workers as a major source of productivity decline in the construction industry. Adrian (1987) examined the impact of shift work on productivity and suggested that productivity would improve by scheduling more difficult tasks earlier in the day. Brocherding *et al*., (1980) studied motivation and productivity on large projects at the crew level. Horner and Talhouni (1990) examined the productivity of bricklaying gangs based on a study at seven different sites. Thomas *et al*., (1990) studied masonry productivity in seven countries using standardised procedures.

Review of the literature indicated that there is no agreement among early researchers on the factors affecting construction labour productivity. Talhouni (1990) cited delays, length of work days and gang composition as important factors influencing labour productivity. Whitehead (1990) argued that methods of working, buildability, bureaucratic constraints (contractual, tendering), weather and climate conditions and variations in working hours are among the important factors affecting productivity. Hass *et.al*., (1999) cited ineffective management as the primary cause of poor productivity rather than an unmotivated and unskilled workforce. Hass *et.al*., argued that there is no doubt that management effectiveness ultimately determines profitability in most cases. Allen (1985), states that the main reason for poor productivity in the construction industry is due to absences and the unavailability of skilled labour. In a survey by Adrian (1987), during the construction of a power plant, it was reported that labour selection methods, skill shortages, unmotivated work force, delays and interruptions are among the main factors affecting productivity in construction projects. Radosavljevic and Horner (2002) suggested that “labour intensive work, unique design, the number of factors affecting on-site work and other variables make the construction industry unstable in its performance”. Here the labour intensive nature of the industry was recognised among the main factors, which suggest that more research focusing on improving labour productivity is required.

2.10 **Productivity Measurement**

Many researchers (Drewin 1982; HM Treasury, 2001; Horner and Duff, 2001; Sumanth, 1984; Shaddad and Pilcher, 1984; Thomas and Yakoumis, 1987) have advocated that productivity refers to how well an economy uses the resources it has available by relating the quantity of inputs to outputs. There are several measures of this relationship. The choice of measure for labour productivity depends not only on its purpose, but critically on the data available. Labour productivity can be defined as the ratio of output resource to input resource. Both output and input can be defined in many different ways, which makes it possible to have different measures of labour productivity.

For this part of the research the objective is to measure labour productivity at the task level in order to identify the factors that may influence productivity and therefore where the opportunity for improvement might lie. At the micro level, productivity is concerned with performance efficiency and as such is concerned with the relationship between an actual and estimated level of performance. These measures of productivity are useful for determining performance efficiency at the task level.

The following sections will explore the measures of output such as gross output, gross value added, earned value, earned hours and the amount of work completed. As well as the measures of input including number of people employed, number of hours worked (actual time) and cost of labour.

2.10.1 Measures of output

In the construction industry, there are several ways in which output may be measured:

Gross output or value measured in cash terms; this includes the value of materials incorporated in the work completed which may confound measures of labour productivity. Gross-output based labour productivity tracks the labour requirements per unit of (physical) output and it can help in the analysis of labour requirements by organisation or industry sector. Although it is easy to measure, since labour productivity is a partial productivity measure and reflects the joint influence of a number of other inputs, the measure does not differentiate between technical change or the productivity of the individuals in the labour force (OECD Manual, 2001).

Gross Value Added (GVA) which is the total output minus the value of all bought in services. It is a measure that is simple to derive, and which can be used at the macro level, but lacks the required granularity for use at the micro level. In theory, its use is only valid if the contribution to GVA of any one input is independent of the contributions from other inputs (Crawford and Vogl, 2006). The measure is used in the analysis of micro-macro links, such as the industry contribution to economy-wide labour productivity and economic growth.

Earned Value which is the amount a contractor will be paid for the work completed; Earned Value systems have been setup to deal with the complex task of controlling and adjusting the baseline project schedule during execution, taking into account project scope, timed delivery and total project budget (Vanhoucke, 2009).

Earned Hours (Estimated Hours) this measures the output in terms of the standard number of man hours input required or estimated to complete a repair task. This method requires the determination of the standard duration of a repair and maintenance task (Horner and Talhouni 1990); productivity may then be defined as the ratio of earned or estimated to actual hours. This measure is widely used in the petrochemical industry (Page, 1982), but has found little favour in construction, possibly through a lack of familiarity.

Amount of Work Completed, e.g. m3 of concrete poured or m2 of brickwork laid is considered as a measure that is clearly understood and is readily available for valuation purposes within construction projects. It cannot however, be easily or clearly implemented within building maintenance due to the nature of the maintenance and repair work; in addition to the lack of clear standards and norms against which this can be measured.

2.10.2 Measures of input

Input may be measured in terms of:

Number of people employed; being a reasonably reliable national statistic for many countries, it is usually used at the macro level when international comparisons are made. It fails however, to take account of differences between numbers employed part-time and full-time.

Number of hours worked (Actual Time); at both the macro and micro levels, the number of hours worked is frequently the preferred measure of input providing relevant statistics are available, (Ruddock and Ruddock, 2011). The number of hours worked may be measured in terms of total time, available time or productive time, (Horner and Talhouni, 1995). Total time is the time for which an employee gets paid, available time is total time less unavoidable delays, mainly due to weather conditions and rest breaks, whilst productive time is available time minus avoidable delays, or the time during which an employee is engaged in a value-adding activity.

Cost of labour; this measure takes into consideration the difference in labour hourly costs according to normal and premium time working (payments made for overtime working), and any additional payments made for productivity-related pay, working conditions, or a number of other variables.

2.10.3 Measures of productivity

Productivity data is important for formulating strategies and for evaluating the effectiveness of productivity improvement policies and programmes (Chau and Walker 1988). In construction, productivity can be measured at different levels. Macro and micro level measurements have different purposes: macro level measurement is concerned with measuring at industry wide or organisation wide levels and is necessary for formulating policies and setting budgets, however, at the operational level, they are of no value; micro level measurements measure productivity at the task level and therefore have the potential to provide useful information for operational managers and supervisors to address productivity issues (BFC, 2006; Dozzi and AbouRizk, 1993).

Since construction activities are normally labour intensive, productivity at the activity/task level is frequently referred to as labour productivity. Horner and Duff (2001) suggest that there are two main reasons for measuring labour productivity on a construction site. These are:

- To improve performance and provide accurate estimating data. This can be achieved by measuring productivity of activities that contribute the most to the overall spend
- To ensure effective utilisation of labour. This can be achieved by recording idle time (non-productive time).

At the micro level, we evaluate the relative merits of measured output per hour of input, earned value/actual cost and earned hours/actual hours worked.

2.10.3.1 ***Output per hour***

This is a traditional measure of productivity which is used widely in a range of standard estimating books and which historically lay at the heart of payment by results schemes. The advantage of this method is that it takes into account variations of number of hours worked per worker, rather than the numbers of employees, as the measure of labour input. With an increase in part-time employment, hours worked provides the more accurate measure of labour input. But the main disadvantage is that the hours worked data is less reliable than the employment data. Data collection is difficult not only because of the large number of activities that have to be measured on a typical construction site, but because of the need to assign work force hours to each activity. The recording of time spent on an activity is not popular with either management or workers.

2.10.3.2 ***Earned value***

This is the value of work output, usually measured by multiplying the quantities of work completed by the corresponding unit rates in the bill of quantities. It is therefore relatively easy to measure, since it is required for valuation purposes (Wilkens, 1999; Mattos and Delarue, 2008; Anbari, 2003). In the context of labour productivity, it suffers from the inclusion of material costs in the measure. Whilst labour productivity can be improved by innovation in materials technology, the inclusion of material costs in a measure of productivity can have serious effect in gaining an understanding of the performance of labour. Actual cost is more difficult to measure at an activity level, but also because of the need to assign the costs of material and plant to an activity. In many cases, this is not straightforward. For example, how is the cost of re-used timber or the cost of a crane to be assigned to a single, particular activity? Thus, on the rare occasions when earned valued analysis has been used, it is typically applied only at the project level.

2.10.3.3 ***Earned hours/Actual hours***

This productivity ratio or index can be used for examining the efficiency of a tradesman on one task or it may be averaged to examine the efficiency of an organisation (Tuttle, 1981). The Earned Hours measure is used extensively within the petrochemical industry (Page, 1982) and within the maintenance operations of the US Air Force (Tuttle, 1981).

It is also used within the construction industry, however, its use is rather limited (Horner and Talhouni 1990; Mattos and Delarue, 2008). This measure is considered to be understandable and quantifiable and offers useful information to managers and supervisors in order to improve productivity at the task level.

2.11 Building maintenance productivity

Maintenance productivity within manufacturing and industrial operations has received a great deal of attention. Lofsten, (2000) explored measuring maintenance performance by identifying an applicable maintenance productivity index. Kumar, (2006) discussed issues relating to the development and implementation of maintenance performance systems and maintenance indicators in infrastructure and industrial assets. Al-Najjar, (2006) discussed the maintenance role in maintaining the quality of the essential elements contributing to the manufacturing process such as production/operation. He further explored the interactions between maintenance, production and quality, and how simple technical effects of maintenance at the operative level can be transferred to the economic effect in the strategic level influencing company's profitability and competitiveness. Alsyouf, (2007) examined how effective maintenance policy could influence the productivity and profitability of a manufacturing process. Weinstein, *et al*, (2009) examined management improvement approaches in controlling costs of quality and maintenance in industry. Muchiri, *et al*, (2010) demonstrated that performance indicators in manufacturing maintenance are not defined in isolation, but are the result of interaction with other organisational functions, in particular production. Czumanski and Lodding, (2012) presented a state oriented approach to identify and prioritise the different impacts on labour productivity for subsequent process enhancement. Loera, *et al*, (2013) focused on the development of a methodology to assess labour productivity of industrial maintenance projects.

Maintenance as an important support function in business with significant investment in physical assets plays an important role to achieve the organisational goals (Kumar, 2006). It is expected that once constructed, all buildings are expected to stand for a number of years regardless of how they may have been designed and constructed. Building maintenance is seen as a way to maintain the economic value of the building (Pitt *et al.*, 2006). For any building maintenance activity, allocated tasks are set up in order to manage a whole range of activities, thereby ensuring efficient building maintenance. Although there are various definitions of building maintenance, a simple one is to keep a building in a condition appropriate to its use. Son and Yuen (1993), stress that adequate maintenance of a building covers many aspects of work, which may be grouped into four categories. These are: first, planning and execution of day-to-day maintenance that includes activities such as servicing, cleaning and inspection of facilities and components; second, rectification works to the building because of design shortcomings or inherent faults in the use of materials; third, the replacement of any high cost items, and finally, maintenance may also embrace aspects of retrofitting or modernisation work such as alteration, addition and enhancement to existing buildings.

The construction industry in general and building maintenance in particular are very labour intensive and any improvement in labour productivity will reflect significantly on an organisation's overall productivity. Similar to the manufacturing industry, building maintenance productivity tends to be very low. According to Hartmann (1986), only 35% of the time available is productively utilised in the average United States Plant which leads to higher maintenance costs.

The nature of building maintenance work makes it an unproductive and costly operation. This is due to its varied tasks and operating environments, which in addition to inadequate management; involves delays, waiting time and coordination issues. There is therefore, potential for improving building maintenance labour productivity.

As can be seen from the brief summary of literature presented, very little research has been conducted in the area of productivity of labour in building maintenance operations. Furthermore, there is no evidence of any research examining maintenance labour productivity at the basic task level which is the focus of this research.

2.11.1 Measurement of building maintenance labour productivity

Similar to the construction industry the objectives of measuring building maintenance labour productivity are to improve performance and to ensure effective utilisation of labour. Measurement of construction labour productivity was the subject of many studies as indicated in section 2.10 where productivity measures specific to the construction industry were developed and generally applied. The literature review however, did not identify any research carried out to measure building maintenance labour productivity. In this research it is therefore proposed to apply productivity measures used within the construction industry to the measurement of the productivity of labour carrying out building maintenance.

2.11.2 Factors influencing building maintenance labour productivity

As highlighted in section 2.9, there have been many studies on the factors influencing construction labour productivity. El-Haram and Horner (2002) conducted a survey among Local Authorities and Housing Associations in Scotland to establish the relative importance of the factors affecting housing maintenance costs. Their findings showed that factors such as high tenant expectations, budget constraints, improper use of the property, energy costs and the right-to-buy policy were the most significant. These factors however, are not relevant to the discussion on building maintenance labour productivity. The literature review did not identify any research that is primarily aimed at identifying the factors influencing building maintenance productivity. It is important therefore to understand and appreciate the factors that may adversely affect labour productivity and work to minimise or eliminate the causes of these factors in order to ensure maximised levels of productivity improvements. By examining the factors influencing construction productivity, this research seeks to identify those factors that may also impact building maintenance productivity.

2.12 **Productivity Improvement**

As indicated in section 2.7 productivity is the efficiency with which an organisation converts inputs into outputs. Since labour represents the largest cost for many organisations, labour productivity has special importance and vitally affects competitiveness. Drewin (1982) suggested that productivity can be increased by improving levels of capital investments, by improving the skills of workers, or by the introduction of new technology and greater efficiencies in the use of existing technology. It is accepted that productivity improvements produce many benefits, but productivity cannot however, be improved without incurring costs. Examples are costs for research and development, training, and the more direct costs of studying current productivity and designing and implementing better methods. Horner and Duff (2001), state that improving productivity is as simple as to reduce it and argue that selecting and training labour carefully, planning the work in detail, keeping the size of the workforce small and avoiding overtime working will lead to improved productivity.

In order to improve productivity it needs to be measured as described in section 2.10.1. Kheon and Brown (1986) contend that to improve productivity, the impact of each factor influencing it should be assessed by statistical methods and attention given to those particular parameters that adversely affect productivity. This view is shared by a number of researchers, (Dai *et al*., 2009; Shaddad and Pilcher 1984) and others.

The literature indicates that many studies have been conducted into improving the productivity of the construction industry (Horner and Duff, 2001; Al-Hajj and Horner, 1997; Dai, et.al, 2009; Shaddad and Pilcher, 1984; Chan, 2002; Song and AbouRizk, 2008; Yakubu and Sun, 2010; Saket, 1986; Noor, 1992; Al –Hajj, 1991; Whitehead, 1990; Talhouni, 1990; Marenjak, 2004). Furthermore, productivity improvement has been the subject of many studies and research projects across many industries. Increasing maintenance productivity in particular has featured extensively in the literature with particular emphasis on the manufacturing industry where productivity improvement techniques such as lean maintenance, Just-in-time, total productive maintenance, 6 sigma 5S's etc. were used (Wireman, 2007; Duffuaa and Al-Sultan, 1997; Raouf and Ben-Daya, 1995; Alsyouf, 2007; Loera, *et al*, 2013; Lofsten, 1998; Czumanski and Lodding, 2012; Weinstein, *et al*, 2009; Kumar, 2006; Al-Najjar, 2006; Muchiri, *et al*, 2010; Coetzee, 1997; Swanson, 2001).

2.12.1 Improving building maintenance productivity

As highlighted in the previous section productivity improvement is an important topic for many industries including construction. Within manufacturing and industrial maintenance there have been many studies on improving maintenance productivity. There is however, a dearth of research focusing on improving the productivity of labour within building maintenance operations. This is one of the areas which this research project is aiming to address. In this research consideration will be given to the application of those productivity improvement approaches used in other industries to building maintenance where appropriate.

2.13 Summary and Conclusions

Building maintenance plays an important role in ensuring that buildings are kept in a safe condition and are fit for use from health, safety and environmental aspects. Adequate maintenance provision will ensure that the life of a building is extended and that overall maintenance costs are reduced.

The review of the literature highlighted the need to optimise maintenance strategies in order to ensure effective use of resources as well as ensuring the right maintenance tasks are carried out in the right way at the right time. Maintenance optimisation methods were identified to be either quantitative models that are concerned with determining optimal maintenance intervals, or qualitative models that have the potential of reducing the number of maintenance tasks which is the objective of maintenance optimisation in this study. The qualitative models included Whole Life Costing (WLC), Total Productive Maintenance (TBM), Failure modes and Effects Analysis (FMEA) and Reliability Centred Maintenance (RCM). It was highlighted that RCM which is a technique of Integrated Logistics Support (ILS) is primarily concerned with minimising maintenance costs by balancing the cost of different maintenance strategies.

The large body of knowledge found in the literature on ILS indicated that it is an important topic in maintenance management. While ILS techniques were found to have been used within various industrial settings including the construction industry there was no evidence to indicate its application to a single building system such as the Rain water Goods (RWG) which is part of the subject of investigation in this study. The various ILS techniques were reviewed. Techniques such as reliability analysis, availability analysis, supportability analysis and level of repair analysis were found to be best applied at the design stage and that they require specific failure information that may not be readily available within the building maintenance provision. It was decided therefore, that FMEA and RCM could be tailored to demonstrate their application to a single building system (RWG) in order to reduce the number of maintenance tasks and their associated costs through identification of the most appropriate and cost effective maintenance strategy.

As well as identifying the appropriate maintenance strategy, the productivity of the maintenance operation and in particular labour productivity needs to be considered. Productivity is considered among the important factors that affect the performance of any organisation. Productivity may be viewed as partial productivity, considering only one factor of input such as labour or total factor productivity considering all input factors such as material, labour, plant and capital. However, due to the labour intensive nature of the construction industry and building maintenance activities, labour productivity will be the focus of this research.

It has been established that productivity measures how much we produce per unit input. The literature identified a number of ways for measuring labour productivity depending on the reason for measurement and the availability of useful data. Measures of productivity include output per hour worked, earned value and earned hours.

The literature review has found that measurement of building maintenance labour productivity has not been the focus of any previous studies. Indeed no measures of productivity for building maintenance were identified. Accordingly productivity measures developed for the construction industry will be applied to building maintenance. While each of the measures has its advantages and disadvantages, for this research project and due to the nature of available data, the preferred measure of labour productivity in building maintenance operations is Earned Hours expressed as estimated hours divided by actual hours.

Productivity influencing factors need to be identified and recorded in order to develop a productivity improvement plan to mitigate their effect. A considerable body of literature exists on the factors influencing construction labour productivity. There was however, very little research conducted on understanding the factors that affect building maintenance performance. Indeed there is no record which the researcher could find to suggest that the factors influencing building maintenance labour productivity having been identified or studied.

The topic of productivity improvement has received considerable attention in the literature. Productivity improvement techniques were identified and implemented across many industry sectors, including the construction industry. Accurate performance data, regular monitoring of performance, understanding of the factors influencing productivity and the availability of resources are among the essential elements identified in the literature for any productivity improvement initiative. There was no approach identified for measuring and understanding the factors influencing building maintenance productivity for the purpose of devising a plan to improve labour productivity.

Chapter 3: Research Methodology

PART 1 – METHODOLOGY FOR SELECTING MAINTENANCE STRATEGY

3.1 Introduction

The objective of part one of this research project is to explore the potential to reduce the number of maintenance tasks and consequently the maintenance costs by selecting the most appropriate and cost effective maintenance strategy. The methodology to be followed here is to apply FMEA and RCM analysis to a selected case study to identify the most appropriate maintenance strategy to maintain a building rainwater goods system.

The objectives of maintenance are defined by the functions and associated performance expectations of the asset under consideration (Moubray, 1991). When applying RCM to determine a maintenance strategy, it is important to consider that these strategies must answer accurately the following questions: what are the main system functions to be preserved? What are the functional failures? What are the failure modes? What are the failure mode causes? What are the failure effects? What are the failure consequences? What are the applicable and cost effective tasks? What are the remaining options?

In answering these questions, the RCM process employs many methods and tools according to a structured and properly documented sequence. In this research Failure Modes Effects Analysis (FMEA) will be used to develop a maintenance strategy in accordance with RCM specifications.

The relationship between RCM and FMEA is illustrated in Figure 3.1, adapted from

Braaksma, (2012). The end result of the FMEA process is used as input to make a RCM based decision which determines the optimal maintenance strategy of an asset.

Assessments and decisions taken within FMEA greatly influence the RCM decisions and thus the quality of the maintenance concept.

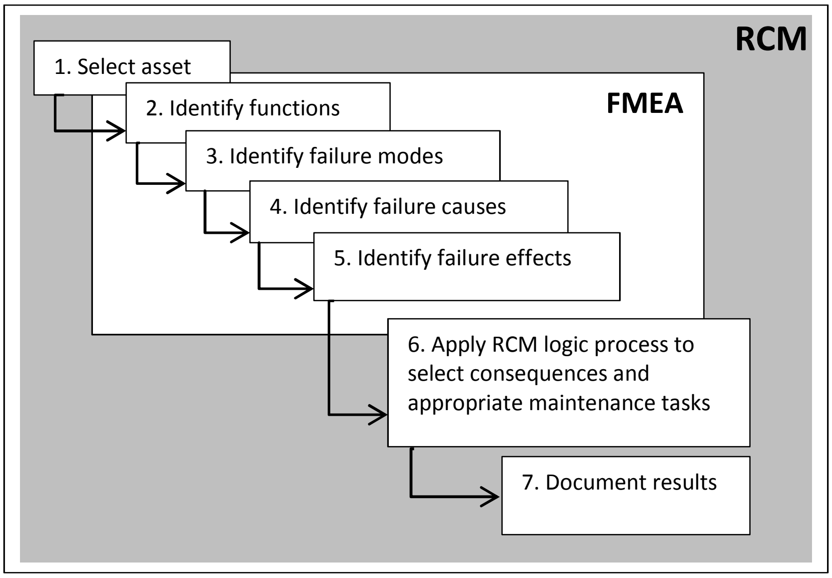

Figure 3:1 FMEA as part of the RCM process, adapted from Braaksma (2012)

3.1.1 Use of case study methodology

The case study approach was deemed appropriate as a means of exploring the application of ILS techniques to a single building system and the lessons that may be learnt as a result of such application. The case study will seek to compare the existing maintenance strategy employed by the data sources with the strategy that result after the application of ILS techniques. The case study method is defined as an in depth study of a particular situation to identify the various interactive processes at work. Gurnmesson (1999) has summarised the advantages of the case study approach as a free and wide choice of data generation and analysis techniques; access to reality and validity in focus for the purpose of understanding. These are some of the reasons for the choice of a case study approach in this research. Yin (2003) states that a case study allows researchers to focus on a case and retain a holistic view and real world perspectives. As to the appropriateness of a case study based on a sample of one, Flyvbjerg (2006) concluded

"*One can often generalize on the basis of a single case, and the case study may be central to scientific development via generalization as supplement or alternative to other methods. But formal generalization is overvalued as a source of scientific development, whereas "the force of example" is underestimated"*.

When conducting research, the case study is an important method, as it allows the researcher to focus on a specific instance or circumstance, and to attempt to identify the various linked processes at work. The case study method is also appropriate for individual researchers since it gives a chance to view a problem to be studied in depth. A further consideration of the case study methodology is relating to the selection of either a single case study or multiple cases, and numerous levels of analysis (Eisenhardt, 1991; Yin, 2003). In designing case research a key question is the number of respondents. The single case can be used to determine whether a theory's proposition is correct or whether some alternative set of explanations may be more relevant. It is also appropriate to use this strategy when the case represents a unique case (Yin, 2003).

3.1.2 Case study data collection

Data collection method for the case study consisted of a search of the literature to identify, study and adapt the steps for applying the selected ILS techniques to a particular building system. The data collection also involved determination of the current maintenance strategy employed to facilitate comparison of maintenance strategies.

3.2 Steps for applying Failure Modes Effects Analysis (FMEA)

It is essential in the application of FMEA to decide which asset, system or element needs to be examined. This is important in order to define the scope of the examination and to enable the next steps of the process to be carried out.

3.2.1 Developing an integrated physical and functional model

The starting point is to develop the physical model of the RWG system. The main function of the system is to collect, convey and discharge rain water safely and efficiently away from a building. The main components of a RWG system to be considered as part of this case study are gutters, gutter outlets, pipes and fixings.

3.2.2 Cross Mapping Physical and Functional Models

The functional model defines the reasons for the presence of the physical elements. Each physical element within the system may perform one or more functions, and therefore to determine the effects of the failure of an element on the system, it is important to understand its functionality.

3.2.3 Identifying Failure Modes

Once the function(s) of each system element has been identified, the next step in the application of FMEA is to identify all possible failure modes for each element of the RWG system that are likely to cause each loss of function. El-Haram and Horner (2003) define a failure mode as a description of the way an element fails. There are many factors that may cause an element to fail, including the type of material, manufacture method, method of incorporation into the system, and environmental conditions.

3.2.4 Identifying Failure mode causes

Once all failure modes are identified, it is important to identify the cause of each failure in sufficient detail to ensure that time and effort is not wasted trying to treat symptoms instead of causes. Equally, it is important to ensure that time is not wasted on the analysis itself by going into too much detail (Moubray, 1991). The objective of this step is to identify all the likely reasons why the failure mode occurred. Since preventing the failure mode means eliminating or controlling its causes, it is important that all possible causes of each failure mode are identified (Kumar *et al*., 2000). There could be many reasons for a failure to occur; poor design, poor material selection, misuse, ageing and/or lack of maintenance are some of the reasons put forward by El-Haram *et al*. (1996).

3.2.5 Identifying the failure effects

The failure effects are the impacts of each failure mode on the element function(s) (Kumar *et al*, 2000). The aim of this step is to identify what happens when each failure mode occurs. According to Kumar *et al*. (2000), failure effects answer the question "what impact a failure mode has on an item function(s) and ultimately on the whole system"? The effect of an item failure depends upon the function of the item in the system. The failure effects can be divided into three levels:

- Local Effect (LE) (item level) – the impact on a system of a failure mode of one of its constituent items, for example, the impact on the function of guttering of a broken gutter support.
- Next Higher Effect (NE) (element level) – the impact of the failure mode on another element of which the considered element is a part, for example, the impact on the function of a wall of the failure of the guttering.
- End Effect (EE) (building level) – the impact of the failure mode on the whole building, for example, the impact on the function of the whole building arising from a broken gutter support.

The aim of any corrective action identified at the end of the analysis will be to overcome both the failure cause and the failure effect. Furthermore, identification of failure effects will play a role in determining the criticality of failure if and when

Failure Mode Effects and Criticality Analysis (FMECA) is carried out. Criticality assessment will not be considered as part of this research for the following reasons:

a. failure modes are used only to complete the RCM process
b. as the research is concerned with exploring the potential for applying FMEA qualitatively, criticality is not used as it is a quantitative part of the analysis.

3.3 Steps for applying Reliability Centred Maintenance (RCM) Analysis

As previously indicated, the concept of RCM has been adopted across several industry sectors as a means of optimising a maintenance strategy. RCM recognises that maintenance is actually far more about preventing or mitigating the consequences of failure than about preventing the failures themselves. In this way, RCM focuses maintenance expenditure where it will be most beneficial. The process of performing an RCM analysis may vary to a certain degree depending on the practitioners and the system's user. The basic RCM steps, however, are common among all applications (Kumar, *et al.*, 2000).

3.3.1 The RCM decision logic

The RCM decision logic process is designed to determine through the use of standard questions, what action should be taken to eliminate or reduce the consequences that result from the occurrence of a failure mode. According to Moubray (1991), within industrial settings, failure consequences are grouped into four categories in the RCM process and are considered in two stages. Firstly, the hidden failures and the evident failures are separated. Secondly, the evident failures are categorised as follows:

- Safety and Environmental consequences
- Operational consequences
- Non Operational consequences.

The RCM decision logic diagram is normally tailored to suit a particular industry sector. The commercial aircraft industry gives safety a very high priority. The nuclear power and the oil and gas industries give safety and the environment a very high priority. The armed forces will place equal emphasis on safety, performance and availability. The construction and the manufacturing industries on the other hand are concerned with both health and safety and operational issues. Therefore, the RCM decision logic structure which was developed for the commercial aircraft, nuclear power, oil and gas industries will be different from that developed for the armed forces and from those for the manufacturing and construction industries. Here the decision logic process used by El-Haram and Horner (2003) will be adapted for use in the application of RCM to the RWG system. This will be discussed in detail in the following sections.

3.3.2 Identifying failure consequences

Failure consequences answer the question "why does a failure mode matter?" the identification of failure consequences is central to the RCM decision process as RCM addresses the consequences of failure rather than the failure itself (Kumar *et al.*, 2000). Identification of the failure consequences will influence the efforts expended on preventing each failure. In other words, if a failure mode has serious consequences, it is likely that more effort is placed on preventing it. On the other hand, if there is no or little consequence of failure it may be decided to perform no preventive action beyond basic maintenance routine. Moubray (1997) states RCM recognises that the consequences of failures are more important than their technical characteristics. In fact, he continues, it recognises that the only reason for doing any kind of preventive maintenance is not to prevent failures per se, but to avoid or at least mitigate the consequences of failure.

Further to the identification of the failure modes through the FMEA, a sequence of questions that form part of the RCM decision logic process will have to be considered. Responses to the following questions will determine the consequence for each failure mode and identify which branch of the decision diagram to follow during maintenance task evaluation (Kumar *et. al*., 2000):

1. Can the user/tenant detect the failure mode?
2. Does the failure mode have an effect on the environment or the health and/or safety of the user/tenant?
3. Is the cost of failure greater than the cost of preventing the failure?
4. Does the failure mode have an effect on the operational performance?
5. Does the failure mode have an effect on the appearance of the building?

3.3.2.1 ***Assessment of Evident and Hidden failures:***

If the answer to the first question is 'YES' then the failure is evident and if the answer is 'NO' then the failure is hidden. Hidden failures are those failures where the user/tenant will not be aware of the incipient loss of function under normal circumstances (Kumar *et al*., 2000). As indicated in Figure 3.2, in the case of evident failure the process continues to consider the remainder of the questions to assess the consequences of evident failures. In the case of hidden failure, questions will be asked to assess whether the failure has an effect on the environment or health and safety. If the answer to this question is 'Yes' then there are environmental or health and safety hidden consequences, if the answer is 'NO' then the failure has economic or operational hidden consequences.

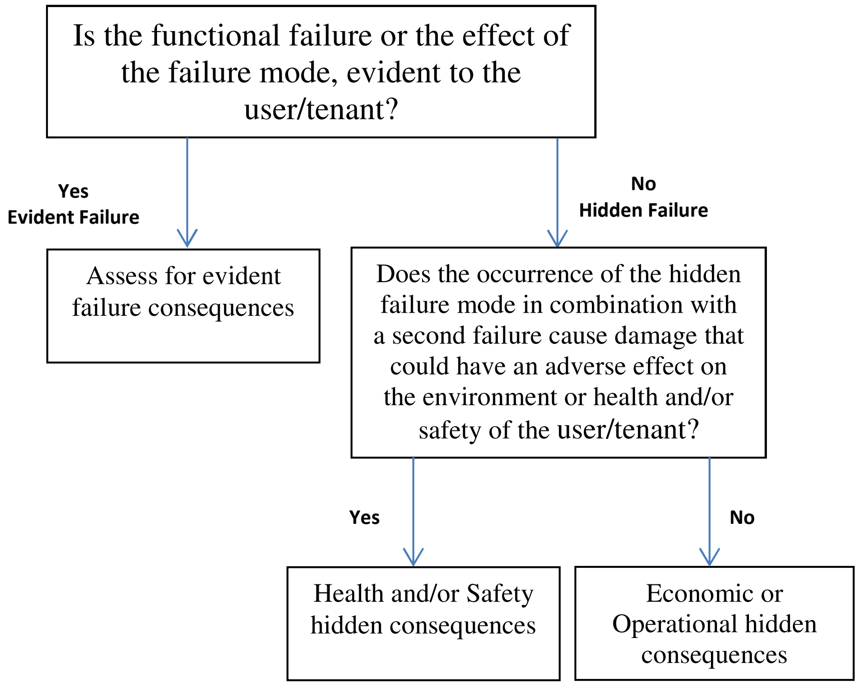

Figure 3:2 Decision logic for assessing Evident and Hidden Failures

3.3.2.2 *Assessment for Health and Safety or Environmental, Consequences:*

Moubray (1997) argues that consideration should always be given first to health and safety consequences because it is unacceptable for people to be hurt in the course of their business. Furthermore, if a maintenance task is worth doing from a health and safety perspective, it will probably also improve performance from an operational view point. On the other hand, Kumar *et, al*. (2000) argue that if a failure mode could affect health and safety, it could also lead to a breach of environmental legislation. Moubray (1997) identified a failure mode as having safety consequences if it causes a loss of function or other damage which could hurt or kill someone. For residential buildings, El-Haram and Horner (2003) expanded this to include the collapse or partial collapse of a building due to defects or deterioration of the building elements. For the purposes of this research, health and safety consequences will be considered together, as it could be argued that any safety concerns will potentially have an impact on the health of the user/tenant. Similarly, as argued by El-Haram and Horner (2003), structural damage to the building could potentially impact the health of the user. A failure mode is said to have environmental consequences if it causes a loss of function which could lead to a breach of any environmental regulations. In this case, the question is asked as indicated in Figure 3.3, if the answer is ‘YES’ then the failure mode has health and safety or environmental consequences and if the answer is ‘NO’ the assessment will continue to the next category of consequences.

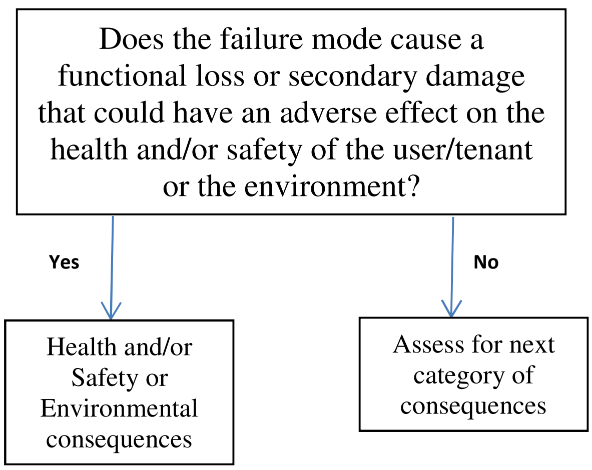

Figure 3:3 Assessment of Health and Safety or Environmental Consequences

3.3.2.3 ***Assessment for Economic Consequences:***

If the failure mode does not affect the health and/or the safety of the user/tenant or the environment, based on the context of buildings the next consideration in the RCM process is given to the economic consequences. This category of consequences is for failure modes that could have an economic significant effect due to the cost of maintenance. The cost of maintenance here refers to the cost of repairing the actual failure plus the cost of lost revenue. If the cost of failure and the cost of its consequential damage is greater than the cost of preventing or repairing the failure, it is said to have economic consequences (Moubray, 1997). In this case, the question is asked as indicated in Figure 3.4, if the answer is 'YES' then the failure mode has economic consequences and if the answer is 'NO' the assessment will continue to the next category of consequences.

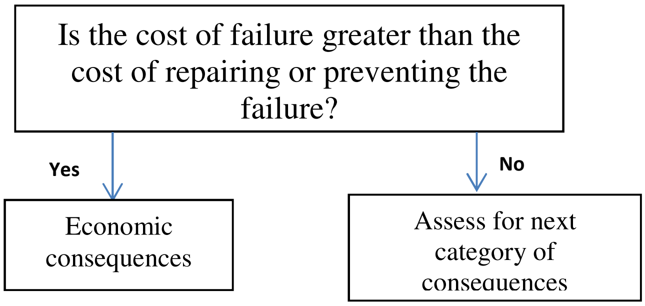

Figure 3:4 Assessment of Economic Consequence

3.3.2.4 ***Assessment for Operational Consequences:***

This category of consequences deals with those failure modes which, should they occur, could have an effect on the operational performance of the element or system. In this case, the question is asked as indicated in Figure 3.5, if the answer is 'YES' then the failure mode has operational consequences and if the answer is 'NO' the assessment will continue to the next category of consequences.

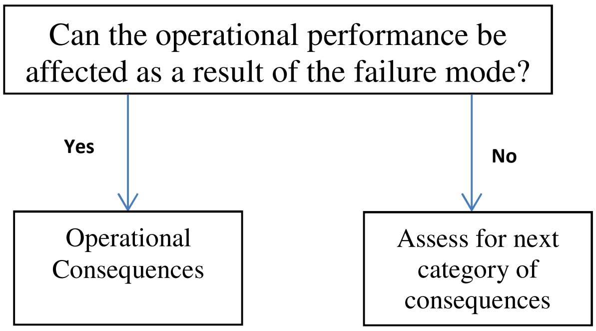

Figure 3:5 Assessment of Operational Consequences

3.3.2.5 ***Assessment for Appearance Consequences:***

A failure mode is said to have appearance consequences if its occurrence results in changing the quality of the original aesthetic appearance of an item or a system (El-

Haram *et al*., 1997). According to Kumar *et al*. (2000), some users may be able to tolerate this category of consequences until there is an opportunity to repair the item or system to its original appearance. There are cases, however, where appearance is paramount to running a business, such as in a prestigious office building or hotels for example. In these cases this could result in operational or economic consequences. In this case, the question is asked as indicated in Figure 3.6, if the answer is 'YES' then the failure mode has appearance consequences and if the answer is 'NO' then it is said that the failure mode has no consequences.

The maintenance action here will either be to do nothing until an opportunity arises to restore the item/building to its original condition or it leads to operational or economic consequences. A cost benefit analysis may be carried out to determine whether a remedial action should be performed.

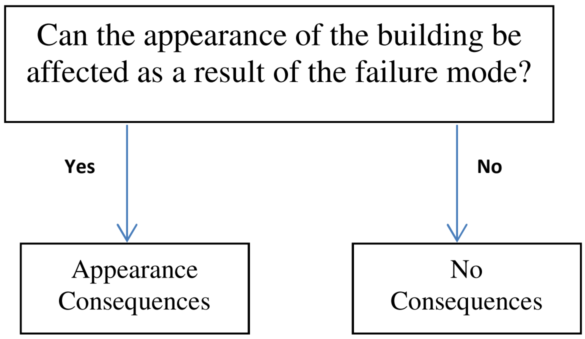

Figure 3:6 Assessment of Appearance Consequences

In summary, the decision logic process to be used for identifying failure consequences of the RWG system is presented in Figure 3.7. It should be recognised that many failures occur without having any consequences (Kumar *et al*., 2000). The fact that some failures could cause harm or injury or affect the health and safety of the user, could constitute a breach of health and safety regulations, or could lead to economic, operational or non-operational effects, does not mean that they will do so every time they occur. El-Haram and Horner (2003) state that in order to identify the health and safety consequences of failure, it is necessary to understand how the building's elements affect the health and safety of the user and the safety of the building. On these occasions, detailed knowledge of design principles and health and safety regulations is required. It is clear, they contend, that failure modes may give rise to multiple consequences depending on the function and operating regime of the elements under consideration. According to Moubray (1997), however, each failure mode is considered in terms of one category of consequences only. So if a building element is classified as having economic consequences, the analysis will not also evaluate its appearance consequences. That is the process will stop when the first category of consequences has been identified. Other consequences may be evaluated as part of any subsequent analysis in the same way as described above.

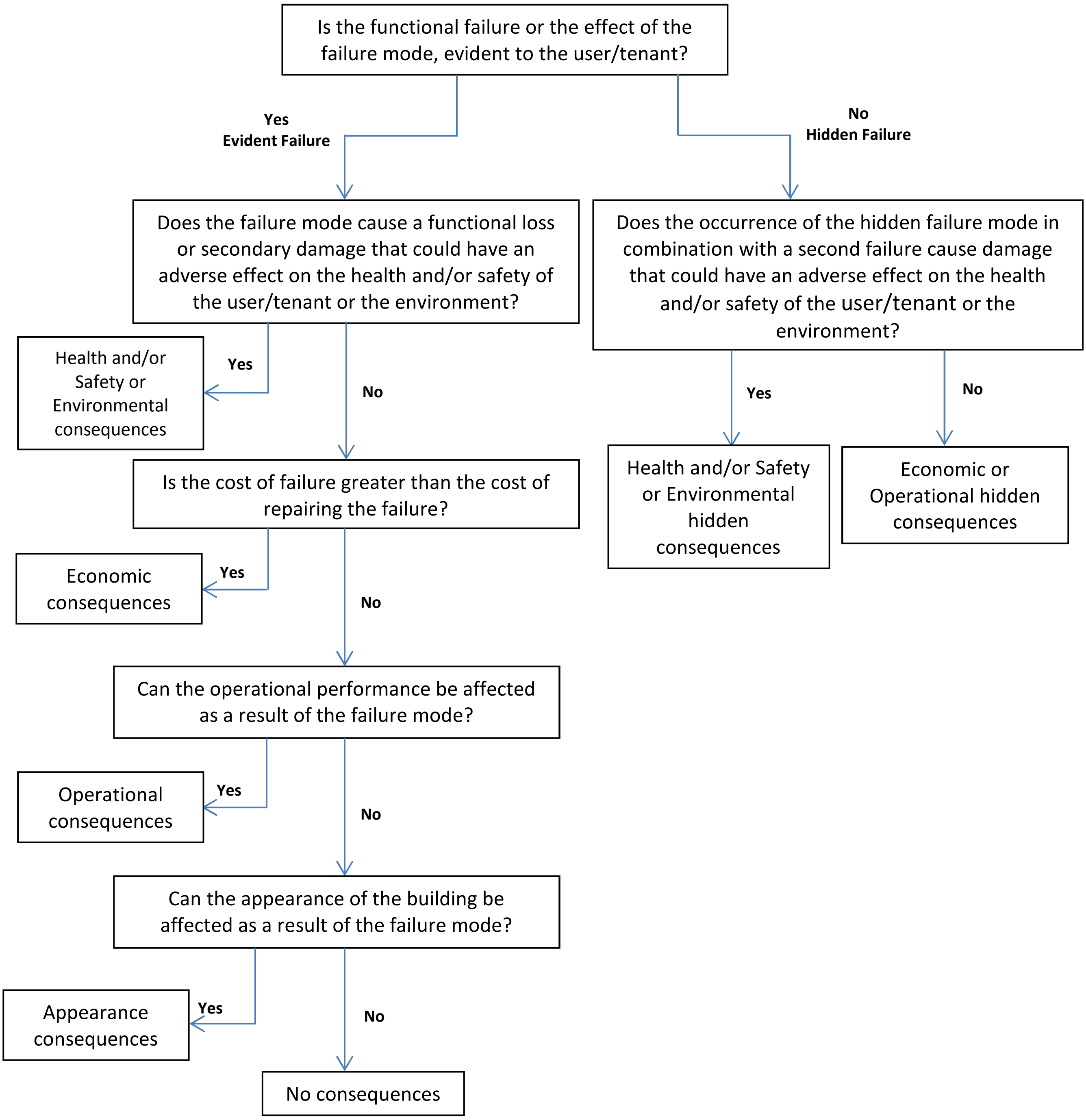

Figure 3:7 Failure consequences decision logic

3.3.3 Maintenance task selection

Every maintenance task requires to be analysed in order to determine the actions that may be required to prevent the occurrence of a failure mode or to reduce its effects to an acceptable level. Accordingly, a preventive maintenance task or combination of tasks may prevent or reduce the probability of failure to an acceptable level. The application of RCM ensures that building maintenance strategies are based on the consequences of failure modes of each element in the building. Choosing the most appropriate and cost-effective maintenance task involves an evaluation of the consequences of each failure mode. There are two main criteria used for selecting maintenance tasks in RCM, in so far as each task must be applicable and cost effective (or worth doing) (Moubray, 1997; Rausand, 1998). A maintenance task is applicable if it can eliminate a failure, or at least reduce the probability of occurrence to an acceptable level or reduce the impact of failure. Cost effectiveness means that the task does not cost more than the consequences of the failure it is going to prevent (Rausand, 1998). Maintenance tasks can be divided into five types, condition-based maintenance, time-based maintenance, failure based maintenance, re-design and failure finding.

Having identified the consequences of each failure mode in accordance with the decision logic diagram in Figure 3.7, the next step in the RCM process is to select the most applicable and cost effective maintenance task or combination of tasks that will deal with each category of consequences.

3.3.3.1 ***Stage one in the task selection process:***

The first stage is to determine that the failure mode does not have any health and safety, environmental, economic or operational consequences. In this case the question is presented as indicated in Figure 3.8. If the answer to this question is 'NO' then the failure mode may have appearance consequences only or no consequences. In this case the correct option is to select an appropriate failure based maintenance task to repair the failure mode or carry out a Cost Benefit Analysis (CBA) to determine whether any action is cost effective. If the answer to the question is 'YES', then other maintenance options need to be considered.

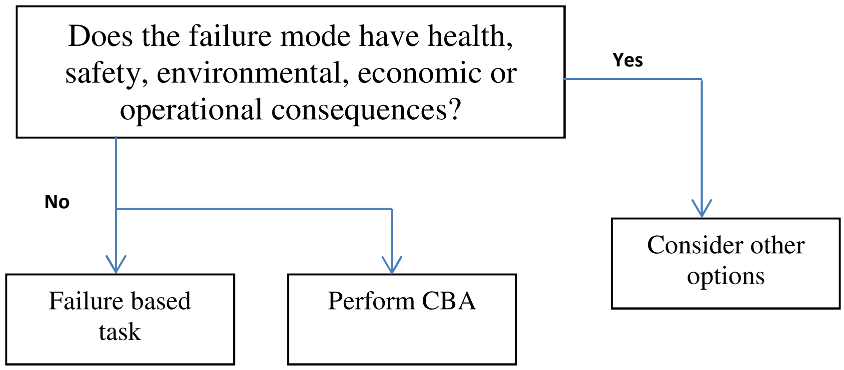

Figure 3:8 Failure Stage one in the Task Selection Process

3.3.3.2 *Stage two in the task selection process:*

If the failure mode is identified as having health and safety or environmental consequences, the RCM process recommends that some action needs to be taken in order to prevent or mitigate the effect of the failure mode. Any preventive maintenance task must be applicable in so far as it will reduce the risk of failure to an acceptable level (Moubry, 1997). If a suitable preventive maintenance task cannot be identified to prevent the failure or reduce its effects to an acceptable level, re-design becomes necessary on the grounds of health and safety (Moubray, 1997; Kumar *et al*., 2000; El-Haram and Horner, 2003). When considering health and safety consequences, no consideration is given to cost effectiveness as taking no action is not an option. This is represented as indicated in Figure 3.9:

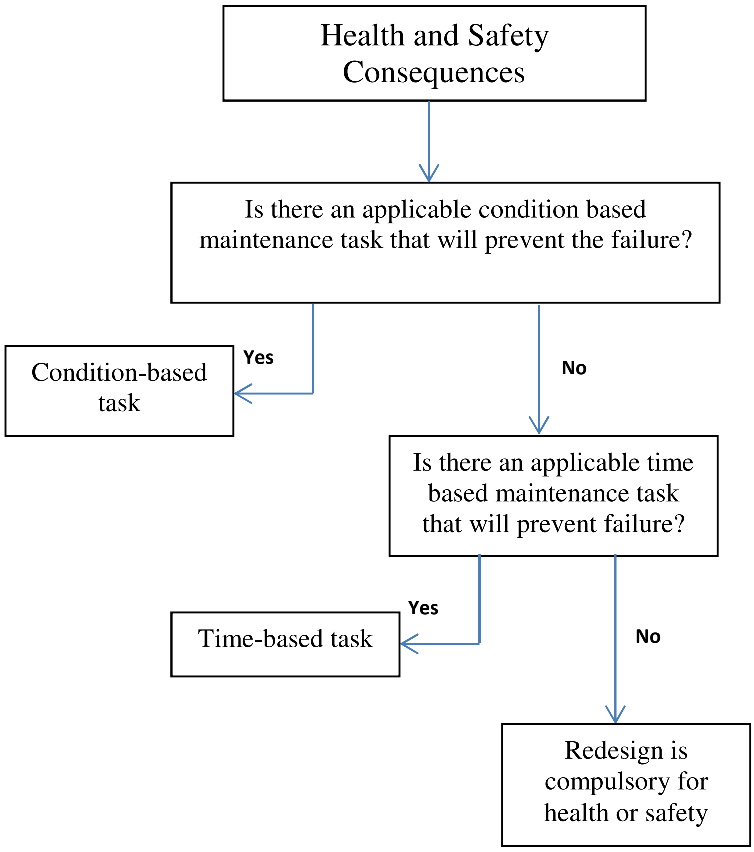

Figure 3:9 Stage two in Task Selection Process

3.3.3.3 *Stage three in the task selection process:*

For failure modes with economic consequences, the consideration here for any preventive maintenance task is cost effectiveness. That is the task is only worth doing if the cost of maintenance is less than the cost of repairing the failure and the cost of the consequential damage. For failure modes with operational consequences a preventive maintenance task is considered worth performing if, over a period of time it costs less than the cost of the operational consequence of the failure it is meant to prevent. That is a cost benefit analysis should be carried out before deciding on the appropriate action. This is represented as indicated in Figure 3.10:

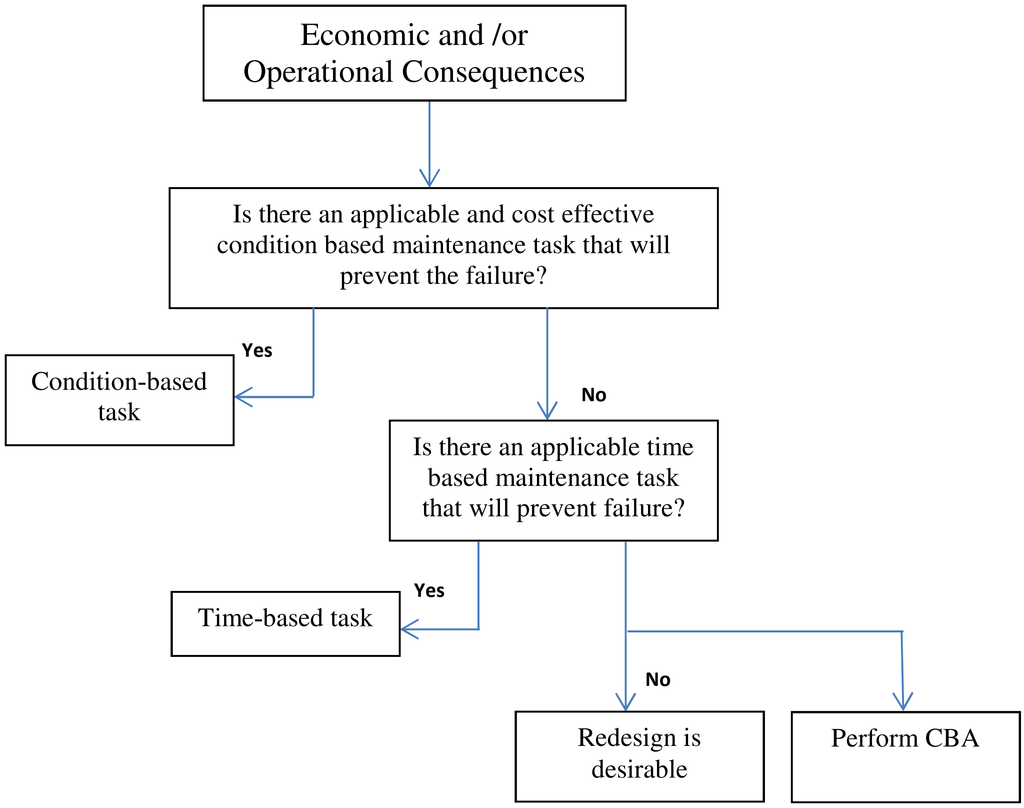

Figure 3:10 Stage three in the Task Selection Process

Smith and Mobley (2008) described the approach used for identifying applicable and cost effective maintenance tasks in terms of a logic path for considering each functional failure. The decision logic process employs a sequence of "yes or no" questions to classify or characterise each functional failure. The responses to these questions inform the logical flow of the analysis and assist in determining the consequences of the functional failure, which could be different for each failure cause. Progression of the analysis determines whether there is an applicable and cost effective maintenance task that prevents or mitigates the failure. The identified tasks (and possibly their intervals) will form a pool of options from which solutions can be generated (Moubray, 1997; El-Haram and Horner, 2003; Smith and Mobley, 2008). The decision logic process highlighted in Figure 3.11 could be used by the RCM analyst to inform the choice of the most applicable and cost effective maintenance task or combination of tasks.

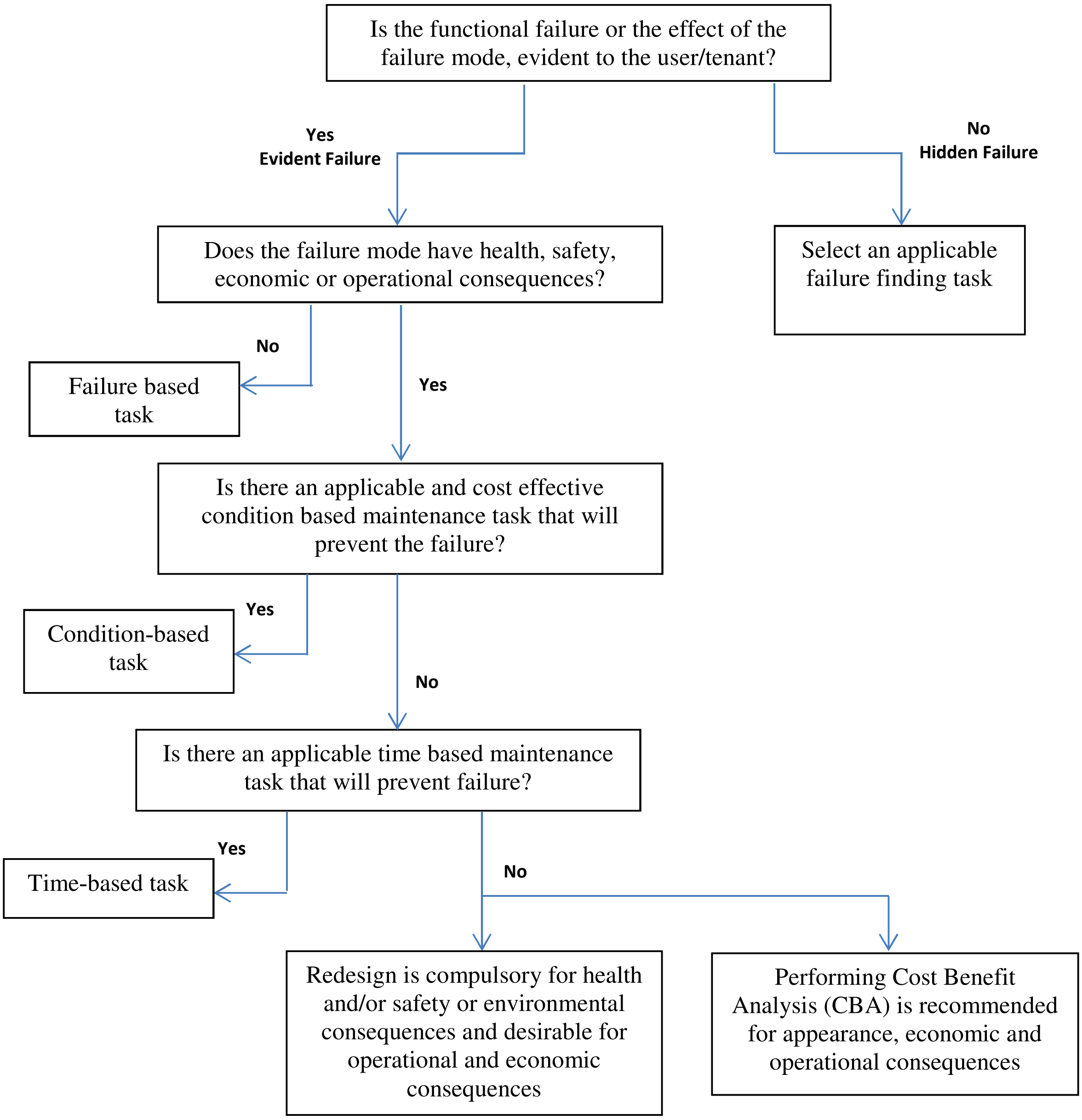

Figure 3:11 Task selection decision logic

3.4 Summary and Conclusions

In order to apply ILS techniques in particular FMEA and RCM to the analysis of maintaining rainwater goods system, the steps required for effective application have been described in detail. Since the application of RCM is about management of the consequences of failures, particular emphasis was given to the critical evaluation of the decision logic diagrams used to identify failure mode consequences and the selection of maintenance tasks. While the logic process for identifying failure consequences was found to be usable, some suggestions were made to clarify the logic process for selecting maintenance tasks. The suggestions were to indicate that in the case of hidden failures, a failure finding task should be selected regardless of the failure consequences as it is necessary to identify the failure before action can be taken to prevent or lessen its effect. The logic process has indicated that if no suitable maintenance task can be identified; re-design is compulsory for health, safety and environmental consequences and desirable for operational and economic consequences. It is suggested to add to this stage of the analysis that Cost Benefit Analysis is recommended for operational, economic and appearance consequences to determine the viability of any recommended action

PART 2 – METHODOLOGY FOR MEASURING BUILDING MAINTENANCE PRODUCTIVITY

3.5 Introduction

This part of the study has two purposes. The first is to better understand the factors that affect maintenance labour productivity from the literature, and through the use of a survey questionnaire rank the identified factors in order of importance. Secondly, by analysing historical repair records, identify and measure the variability in productivity levels among different maintenance tradesmen as well as the variability during the performance of similar basic repair tasks to understand the causes of such variability.

3.6 Research method

Fellows and Liu (2003) discussed five research methods: experiments, surveys, action research, ethnographic research and case study research. Research in the construction industry is most often carried out through experiments, surveys or case studies. Considering the factors that affect labour productivity in the building maintenance sector, obtaining results through experiments will be time consuming as well as being difficult to control and would therefore be expensive. Case studies would not provide results that are easy to generalise as different companies face different problems. Surveys through questionnaires, however, were found to be appropriate due to the relative ease of obtaining consistent data appropriate for achieving the objectives of this study.

Surveys are one of the most frequently used methods of data gathering in social research. The random sampling procedure of the survey allows a relatively small number of respondents to represent a much larger population (Ferber, 1980). The opinions and characteristics of a population can be explained by a representative sample. Surveys are considered to be an effective means to gain useful data on attitudes, issues and causal relationships and they are relatively inexpensive to administer. However, they can only show the strength of statistical association between variables and they provide no basis to expect that the respondents correctly interpret the questions.

3.7 Survey on maintenance labour productivity

A survey questionnaire to solicit the views of maintenance managers on the factors that influence productivity was developed. The objective of the survey was to identify the important factors that affect labour productivity in maintenance operations and to rank these factors in order of importance. The respondents were asked to indicate from a list of factors that may influence maintenance labour productivity, the relative importance of each of the factors to their responsive/reactive maintenance operations. The survey was conducted online using the Bristol Online Survey (BOS) platform and was targeted at asset managers in Scottish local authorities, housing associations and maintenance contractors.

3.7.1 Identifying factors influencing maintenance labour productivity

Because of the dearth of literature on the subject of labour productivity in maintenance activities, an exercise to map the factors influencing labour productivity in construction projects was carried out during the course of this research project. The exercise focused on the works of (Shaddad and Pilcher, 1984; Thomas and Yiakoumis, 1987; and Horner and Talhouni, 1990) who between them have identified a considerable number of factors influencing labour productivity in construction. The mapping exercise as shown in Table 3.1 resulted in the identification of 32 common factors and it was found that almost all those factors could also impact the productivity of labour in maintenance and repair operations.

As a result of the mapping exercise and the identification of those factors that are also relevant to repair and maintenance operations, it was necessary to identify those factors that are considered to have the most effect on repair and maintenance productivity. An internal discussion was conducted that included the researcher and the supervisory team who have extensive experience of maintenance and repair operations in order to determine those factors from the list above that could have the most impact on maintenance labour productivity. As a result a list of 14 factors was drawn up. These factors were then presented to the data sources (CDRMS and HHA) in order to gauge their views as to the appropriateness of these factors; both data sources agreed with the identified factors. There were many factors that were common to all researches or at least two researchers that were not chosen as they were deemed to be more important to construction activities, such as type of payment scheme employed, quality of supervision, complexity of design information and others. Similarly, a number of factors that were only mentioned by one researcher were included as they were deemed to be of more importance to repair and maintenance, such as availability of tools and material, quality of information, access to work site and others.

Table 3:1 Mapping of Factors Influencing Labour Productivity on construction and maintenance operations

No.	Factors Influencing Labour Productivity	Shaddad & Pilcher	Thomas & Yiakoumis	Horner & Talhouni	Relevance to maintenance
1.	The composition of the work crew	X	X	X	√
2.	Level of skill and motivation of workmen	X	X	X	√
3.	The nature of the work site	X	X	X	√
4.	Labour turnover and absenteeism	X	X	X	√
5.	The incidence of delay	X	X		√
6.	Quality of workmanship	X	X		√
7.	Continuity of work for the different trades	X	X		√
8.	The type of payment scheme employed	X	X		√
9.	The level of management control present on site	X	X		√
10.	The type of contract	X	X		√
11.	The degree of mechanisation of the operation	X	X		√
12.	Inconsistent, non-standard work methods, shortcuts or violations	X		X	√
13.	Working hours	X		X	√
14.	Quality of supervision	X		X	√
15.	Complexity of design information	X		X	√
16.	Total number of operatives on site	X		X	√
17.	Proportion of work sub-contracted	X		X	√
18.	Incentive scheme	X		X	√
19.	Learning effects as a result of repetition		X		√
20.	Complexity and size of the work	X			√
21.	Quality of finished work	X			√
22.	Availability of tools and material	X			√
23.	Quality of tools and materials used	X			√
24.	Regulatory requirements	X			
25.	Quality of information, vague/incomplete work instructions	X			√
26.	Insufficient workers	X			√
27.	Access to the work site	X			√
28.	Weather conditions	X			√
29.	Unplanned errors and omissions, work stoppages, delays	X			√
30.	Buildability/Maintainability			X	√
31.	Availability of power tools			X	√
32.	Workers fatigue, stress, morale, sensory limitations	X			√

3.7.2 Questionnaire design

The factors affecting maintenance labour productivity were identified from the literature as described in section 3.7.1. A total of 14 factors were identified. Maintenance managers were required to rank the factors according to their importance on impacting productivity on a five-point Likert Scale with the rating of "5" representing very important, "4" important, "3" somewhat important, "2" not important and "1" don't know. The survey was conducted online using the Bristol Online Survey (BOS) tool.

3.7.3 Pilot studies

Pilot studies were carried out to ensure the clarity and relevance of the questionnaire to maintenance managers. The questionnaire was initially shown to the supervisory team who have experience in conducting survey questionnaires as well as building maintenance. Based on their feedback, amendments were made and on the second phase of the pilot study, the survey was conducted on representatives from the participating organisations (data sources). Based on the feedback, minor amendments were again made to remove any ambiguities and discrepancies. This pilot study was conducted to validate and improve the questionnaire, in terms of its format and layout, the wording of questions and the overall content.

In short, the questionnaire was validated through this process and provided the researcher with the opportunity to improve before launching the main survey.

3.7.4 Sample selection

This online survey was circulated to asset managers within the following types of organisations:

- Organisations that operate their own housing stock/buildings which they are responsible for maintaining such as local authorities and housing associations in Scotland.
- Contracting organisations who are contracted to carry out maintenance and repair work on behalf of local authorities, housing associations or private companies or individuals.

It was anticipated that this would provide different views on how the issue of maintenance labour productivity is dealt with by a variety of organisations.

3.8 Methodology for analysis of historical repair data

Historical repair data for this part of the research was collected from two data sources, namely the Construction Division Repair and Maintenance Section (CDRMS) of Dundee City Council and Hillcrest Maintenance Services (HMS). Initial discussions with the CDRMS indicated their desire to improve the productivity of their responsive repairs service. Although they had concerns over the delivery of the planned and cyclical maintenance programmes, responsive repairs was the area that required immediate improvement. Furthermore, subsequent discussions with HMS who have made a significant investment in a Mobile Working and Work Scheduling platforms aimed at investigating their labour productivity, also agreed to provide data from their responsive repairs operations. The methodology for data collection was to examine historical data of responsive maintenance at the task level. A comparison was conducted between the two organisations and their approach to the issues of recording, measuring and improving labour productivity.

3.8.1 Data preparation requirement

In building repair and maintenance, a maintenance department carries out a large number of repair and maintenance tasks every day. Repair and maintenance tasks are carried out by a large selection of tradesmen such as, Joiners, Plumbers, Electricians, Painters, Glazier, Roofers, Plasterers, Gas and Heating engineers and other specialised trades. .Data was provided by two data sources: a local authority and a housing association for a five month period for all repair and maintenance tasks carried out by each organisation. This resulted in a large number of repair and maintenance tasks (over 12,000 in a 5 month period). In the context of estimating maintenance costs, it is deemed impractical by several authors to assess every component of life cycle costs and it is recommended that attention is directed to those areas that are of greater significance (Bennet *et al*., 1987; Ashworth, 1999). In this research project to analyse all tasks by all trades would not have been an efficient way of analysing the data; hence a method was required to select only those trades and tasks within each trade that have the greatest impact on the overall expenditure in terms of cost and time. For this reason the philosophy of cost/time significance was used.

3.8.2 Cost/Time Significant Items in Building Maintenance

The cost/time significance technique is used to reduce the amount of data to be collected and/or analysed without any reduction of its usefulness or affecting the results of the analysis. Although developed for estimating costs, the principle is reliable and robust to be implemented and used to simplify data analysis in exactly the same way.

In construction, taking on board the 80/20 thinking, many researchers (Shereef, 1981; Saket, 1986; Al-Hajj, 1991) had discovered that about 80% of the total value of items in a bill of quantities is contributed by 20% of the total bill items. The 20% high value items are generally referred to as the cost-significant items (CSIs), though it is not uncommon for researchers to refer to any high value item as a cost significant item (Al-Hajj, 1991). Saket (1986) observed that a large proportion of low value items contributed little to the accuracy of the total value of a bill of quantities. That is to say, these items that were not considered as cost-significant have a negligible effect on the accuracy of the overall value of a bill of quantities. He developed a system of iterative estimating of the bills of quantities, which allows the pricing of a blank bill of quantities using less than 30% of the items. This he proposed is how to identify the cost-significant items. Shereef (1981) defined the cost significant items (CSI) as those items whose value is greater than the mean item value, the mean item value being the total value divided by the total number of items. Saket (1986) tested Shereef's hypothesis on 85 bills of quantities and discovered that on average, 81.5% of the total cost was included in 18.5% of the total number of items.

The advantage of this method is that not all trades or activities are significant as only a few account for most of the cost and analysis of those activities will be feasible. This research is concerned with calculating labour productivity in terms of the Earned Hours and therefore it is the time to complete a repair and maintenance tasks that is important rather than the value. Hence the principle described above will be applied to determine the Time Significant Trades and the Time Significant Tasks. This method would serve to simplify the data and provide a rationale framework for its analysis.

3.9 **Earned Hours Productivity Index (PI EH)**

Measures of productivity were discussed in section 2.10.3. It was established that the Earned Hours measure is considered to be understandable and quantifiable and offers useful information to managers and supervisors in order to improve productivity at the task level. For this measure to be accurate however, it depends on the accurate estimation of task duration and any inaccuracies in the estimated times will provide distorted results. The Earned Hours productivity index (PI EH) measures the output in terms of the standard number of man hours input required or estimated to complete a repair task and is expressed as:

$$\boldsymbol{PI\ Earned\ Hours\ (PI\ EH)} = \frac{\boldsymbol{Estimated\ Hours}}{\boldsymbol{Actual\ Hours}} \qquad (9)$$

This productivity index is a useful measure of how effectively labour resources are utilised in order to identify and address productivity issues. Furthermore, the data available lent itself quite readily for calculating this productivity index. Therefore, this measure of productivity was used in the subsequent data analysis.

3.9.1 Earned Hours Analysis

The standard task duration may be estimated based on historical similar repairs or by using an industry standard such as the Schedule of rates (SoR). These are a list of prices, setting out how much a housing organisation will pay a contractor for different types of repair and maintenance work. There are cases however, where CDRMS used a combination of the two to estimate task duration. Another method of estimating task duration is by measuring task performance directly by observing tradesmen while carrying out repairs. Despite making a request to the data sources, this was not possible to organise. Since current performance is a good indicator of future performance, the estimated times to complete a repair was provided by CDRMS based on a combination of historical repairs data and the SoR, and by HMS as part of the Schedule of Rates used. The actual time to complete a repair was provided by HMS as part of the data recorded on their computerised system. It was not however, readily available from the CDRMS data which necessitated an additional step to calculate the actual hours.

If for example, a repair and maintenance task is estimated to be completed by 1 man in 3 hours, it is said to have an Earned Hour value of 3 man hours. If the repair and maintenance task is actually completed in 2 hours, the productivity index is 3/2 equals 1.5. In other words, the repair and maintenance task was performed 50% more productively than planned.

3.9.2 Calculation of Actual Time to Complete a Repair

The productivity index expressed in terms of Earned Hours is the measure of productivity used in this study. An important parameter in determining the index is the actual time for a repair. Although this parameter was available in the data provided by HMS, it was not available in the data from CDRMS and needed to be calculated. The billing records included the total cost of labour for each job broken down into the charge out rate for each individual tradesman. Once the hourly charge out rate was identified for the various tradesmen, by examining the cost of labour as recorded in the billing record for a particular repair task and dividing by the hourly charge out rate identified, the actual billed time for each repair job could be determined. This is demonstrated in the following example.

Task No. K73174, to remove a wood threshold and replace with a metal one was carried out by tradesmen ID 2035. The total labour cost recorded for the job was £79.30. Given that the call out charge for a joiner is £31.72:

$$\boldsymbol{Actual\ Hours} = \frac{\boldsymbol{Total\ Labour\ Value}}{\boldsymbol{Call\ Out\ Charge}} \tag{10}$$

$$\frac{79.30}{31.72}$$

$$= \quad 2.5\ \underline{\text{hours}}$$

The actual time for all the tasks being examined was calculated according to the above formula.

3.10 **Productivity monitoring methods**

There are several methods described in the literature for monitoring labour productivity. The following sections will discuss the methods and whether they can be adapted for application in measuring the productivity of labour in building maintenance. The methods can be divided into two categories (Noor, 1992):

3.10.1 Continuous Observations

Direct Observation:

Noor (1992) explained that this method involves a trained observer(s) noting the time the workers spend on direct work, contributory work and time spent not working. This method of monitoring can become quite tedious and time consuming when attempting to observe a number of workers at the same time.

Work Study:

This involves direct observation of construction workers. This method only lasts for a short period of time and should correspond to the work cycle monitored. Drewin (1982) stated that this activity can be broken down into two main areas, work measurement and method study.

Work measurement determines the time taken for different tasks within a work cycle allowing for variations from worker to worker. The ultimate aim of the exercise is to establish a standard work time for a given task. Method study focuses on the efficiency of the work method used. Based on the results of the work measurement exercise, alternative work methods with different standard times would be identified in order to determine the most efficient work method for a given task.

<u>Audio-visual methods</u>:

Rather than physically observing the operations as in the direct observation method, audio-visual equipment can be used to continuously monitor the performance of workers. To identify many of the influences that can affect worker productivity, Harris and McCaffer (2006) utilised video recorded time studies in order to identify particular problems on site.

While continuous observation methods have proved very useful in monitoring and measuring labour productivity on construction projects, their application to monitor the activities of maintenance labour could be very challenging. The nature of building maintenance with its diverse tasks and locations does not lend itself for implementation of such methods. The majority of maintenance tasks are usually performed by a single tradesman within a home, an office or other types of functioning building and it would not be practical to easily implement any of the methods described above. There is scope however, for their utilisation during major refurbishment or upgrade work.

3.10.2 Intermittent Observations

<u>Activity Sampling</u>:

Activity sampling involves making periodic observations of operations. In essence activity sampling provides a tool for determining how the time of workers is utilised at the work place. The philosophy behind this method is that if frequent, random observations are made of an activity during the course of a work day, inferences can be made on the distribution of the time workers spend on their daily activities. The accuracy of the activity sampling technique can be improved by increasing the number of observations (Noor, 1992, Drewin, 1982). Strictly speaking, activity sampling is not a measure of productivity since it measures only input and not output.

Craftsmen's questionnaire survey

This method solicits the views of workers concerning the factors which may affect their performance (Noor, 1992). This enables identification of sources of problems and subsequently implementation of appropriate corrective actions. It is not, however a measure of productivity.

Foreman delay survey

In this method of monitoring the performance of workers, only the foreman is questioned on the extent and type of delays that affected the performance of the workers. The rationale for this method is that the Foreman is in close contact with both the workers and management and is able to identify the cause of a delay and give an accurate estimate of its duration (Talhouni, 1990). It assumes that the incidence of delays is a surrogate measure for productivity.

Daily visit method

This method was used by Talhouni (1990) to monitor the productivity of masonry gangs. This method involves the observer visiting a site once a day during the last half hour of the work day and collecting information on the output produced and the working hours. The main advantage of this method is that manpower required for data collection is reduced. Consequently, productivity of more than one type of worker can be monitored with reduced resources.

It is accepted that there is some limited scope to utilise some of the intermittent observation methods for measuring labour productivity within building maintenance. This however, will be challenging due to the nature of the maintenance function where tasks are completed within limited time scales and are almost always performed by individual tradesmen with little or no supervision.

Giving that this research project is concerned with identifying the factors influencing labour productivity and mitigating their effects with a view to improving productivity, data was collected from historical records using computerised maintenance systems.

3.11 Determining variability in productivity levels

Variability is the extent to which data points in a statistical distribution or data set diverge from the average or mean value. Variability also refers to the extent to which these data points differ from each other. There are various measures of variability, the mean, median and mode are measures of central tendency. The mean is the most common measure of central tendency. The variance and standard deviation are measures of variability. They are the most commonly used measures of variability of the data around the mean. The variance is a measure of dispersion of the data around the mean. The standard deviation is the square root of the variance. Other measures of variability include square deviation and average square deviation. The squared deviation is most often used in the analysis of variance (ANOVA) and other related tests. In addition there are other measures of variability that are not linked to the mean such as median absolute deviation, range and inter-quartile range. In this research project only the most commonly used measures of central tendency (mean) and variability (standard deviation) are used as they are easy to calculate and interpret and will provide an understanding of the variability in productivity levels under study.

3.12 Examining the Factors Affecting Labour Productivity

Labour productivity is affected by a large number of factors. These factors will need to be identified and their effects examined in order to improve labour productivity.

For this research, given that no such attempt was made previously to analyse task level productivity, and due to the nature of the data available, it was deemed logical to fully utilise the available data in order to assess all parameters that may impact labour productivity. Using the Earned Hours productivity index (PI EH), it was possible to analyse the following parameters using the techniques and methods described in the previous sections.

1. Impact of Task Performance on Productivity
2. Impact of Tradesmen Performance on productivity
3. Impact of Day of the Week on Productivity
4. Impact of Seasonal Variability on Productivity

The impact of the above parameters on productivity was considered based on historical repair data available with a view to identify the factors that may influence maintenance labour productivity and therefore the potential for productivity improvement.

3.13 Summary and Conclusions

This chapter has discussed the methodology to be followed in the course of this research. Furthermore the individual techniques to be employed for analysing the data were discussed. The methodology involves the following:

- The identification of the significant trades and tasks to be investigated through sorting and partitioning of the data and the use of cost-significant theory to select the trades and tasks.
- Discussion of the various productivity indices considered and the choice of the Earned Hours productivity index and how it is calculated.
- Examining the variability in labour productivity by employing techniques such as Arithmetic Mean and Standard Deviation.

- Assessing the impact of the factors affecting labour productivity, in particular, the task Performance, Tradesmen Performance, Day of the Week and Seasonal Variability.

Chapter 4: Case Study: The Application of ILS Techniques to the Study of Rainwater Goods System

4.1 Introduction to the Case Study

The purpose of this case study is to explore the potential to reduce the number of maintenance tasks and consequently the maintenance costs by selecting the most appropriate and cost effective maintenance strategy through the use of Integrated Logistic Support (ILS) techniques in particular FMEA and RCM. As an introduction to the case study, a justification for the use of ILS and the choice of the case study methodology will be offered as well as justification for choosing Rainwater Goods as the subject for the case study.

4.1.1 Why apply ILS techniques to the analysis of RWG?

As discussed in section 2.3.3, the objective of optimising maintenance strategies in this research is to identify new approaches to reducing the number of maintenance tasks and the costs of maintenance. ILS techniques offer a good potential for optimising maintenance strategies as has been proven through applications within other industries. These techniques will be applied to the maintenance of the RWG system of buildings. . Techniques such as FMEA and RCM offer the potential to analyse a building system, identify the functional elements, how these element may fail, the effects of their failure and the failure consequences. Consideration of these will then identify the most applicable and cost effective maintenance strategies to eliminate the failures or mitigate their effects.

4.1.2 Why RWG?

It is estimated that the average yearly rainfall in the UK is around 750mm www.zen.co.uk/rainfall, so it is essential that properties of all types have well designed and well maintained rainwater collection and drainage systems. Faulty rainwater drainage systems can cause considerable damage to a building. This may arise due to poor fitting, corrosion or material ageing. Euro Inox, (2005) contend that rainwater escaping from the drainage system is a typical culprit in a range of problems, such as:

- Wet or rotting rafters due to defective eaves flashings and gutters
- Damage to underlying structure due to leaks
- Serious damage to the support structure and facings from defective internal guttering
- Facades seriously affected by malfunctioning interlocking sleeves, bends and pipes
- Unsightly patches and loose render.

Leaks are not always noticed immediately. It can sometimes be a matter of years before evidence of damp emerges. By that time the additional damage caused – often hidden – can be considerable and costly to put right.

Over a 5 year period (2007 – 2012) CDMRS recorded total cost of repairs to RWG amounting to £716,000 representing 4% of the total spend on maintenance. Total cost of material during the period was £22,750; that is over the period, labour cost was almost 97% of the total cost of repairs. Table 4.1 indicates the cost of repairs to RWG on a yearly basis.

Table 4:1 Cost of Rain Water Goods repairs (2007 – 2012)

Year	Total Cost (£)	Labour Cost (£)	Total Hours	Material Cost (£)	Total Spend Maintenance (£)	% Contribution
2007	122,297	118,802	4,405	3,494	Unknown	-
2008	149,464	146,223	5,265	3,241	Unknown	-
2009	44,141	42,856	1,348	1,285	Unknown	-
2010	102,580	99,723	3,197	2,857	4,712,295	2.2%
2011	203.603	196,800	6,254	6,803	5,133,211	3.9%
2012	95,434	90,364	2,763	5,069	5,370,185	1.8%

From the data available the following observations were made:

- RWG repairs involved various trades such as bricklayer, scaffolder, drainer, slater, and plumber and on occasions a sub-contractor.
- The bulk of the expenditure is attributable to labour costs which indicate that any improvement to labour productivity will mean a reduction in the cost of maintenance.
- As well as the significant amount of time and cost associated with RWG repairs, there is the potential of damage to other building elements such as roofs, walls, timber etc. due to water penetration which could have serious consequences and will be very costly to repair.

For the above reasons it was decided to work on RWG as the subject for the case study.

4.1.3 Current maintenance strategy

For RWG, the current maintenance strategy employed by Construction Division Repair and Maintenance Section of Dundee City Council (CDRMS) and Hillcrest Maintenance Service (HMS) is that of responsive maintenance so that repair and maintenance tasks are carried out only after failure has occurred. A sample of repairs to RWG carried out by the data sources is included in Appendix A3. The most common responsive maintenance tasks carried out by the two data sources are summarised in Table 4.1.

Table 4:2 Common reactive maintenance tasks for RWG

Guttering	Downpipe
Clean/clear out guttering	Repair leaking downpipe
Repair leaking gutters	Adjust/secure downpipe
Adjust/secure guttering	Replace (all or part) of downpipe
Repair leaks at joints	Clear choked downpipe
Repair/renew outlets	Repair/reseal joints at downpipe

Historically wood, lead, cast iron and to some extent copper were the materials commonly used. Since the 1950s plastics, and in particular uPVC, have come to dominate the market. Plastics appear to offer many advantages over metals, in that they are comparatively light weight, easy to install, and lower capital cost.

In recent years copper and cast iron have come back into fashion as doubts emerged over the efficacy of uPVC (Pullen, 2008) for reasons of aesthetics, life expectancy and whole life costs and people started looking for more sustainable solutions.

The data provided by both data sources has shown that while cast iron rainwater goods are used in some older properties, the majority use uPVC RWG systems. Accordingly, FMEA and RCM will be applied to a uPVC system.

4.2 Application of FMEA

As discussed in section 3.2, the development of FMEA is largely dependent on expert judgment. It should be noted that the aim of conducting the RWG case study is simply to explore the potential of ILS techniques to reduce that number of maintenance tasks and consequently the overall cost of maintenance by selecting the most applicable and cost effective maintenance strategy.

4.2.1 Developing an integrated physical and functional model

4.2.1.1 ***Developing the physical model***

The physical elements of Rainwater Goods to be examined are the downpipes, guttering and other fixtures that take the water that runs off the roof into the drainage system used to take the water away. Rainwater Goods are generally made up of the following items as illustrated in Figure 4.1. https://www.pinterest.com/pin/506795764290650691/ (accessed 1/4/2012).

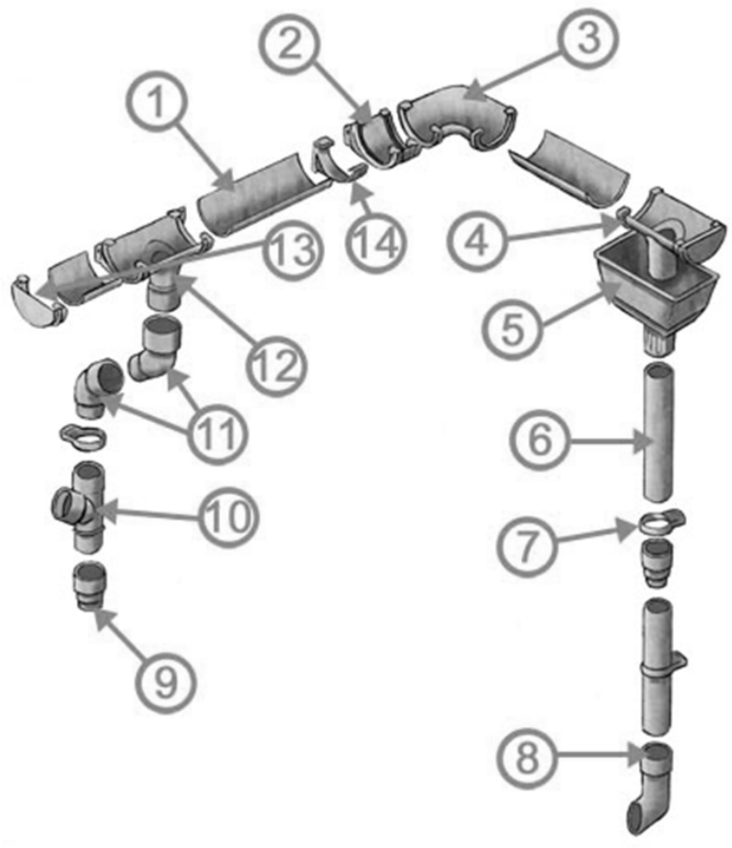

Figure 4:1 Typical Rainwater Goods System

1. Gutter:
2. Gutter Union Bracket
3. 90° Gutter Angle
4. Stop End Outlet
5. Hopper
6. Downpipe
7. Downpipe Bracket
8. Shoe
9. Downpipe Connector
10. Branch
11. Offset Bends
12. Running Outlet
13. External Stop End
14. Gutter Support Bracket

It should be noted that the above represents a complete rainwater drainage system with all components included. Depending on the type and size of a building, not all items would be necessary for the system to fulfil its function.

4.2.1.2 *Developing the functional model*

There are 4 functions associated with rainwater goods, 3 main functions that are essential for the efficient operation of the system and a failure of one of these functions will affect the performance of the entire system, these are the Collecting Function, the Conveying Function and the Discharging Function as shown in Figure 4.2. The fourth function is the Fixing Function, which is to connect parts of the system together and securely fix the other elements of the rainwater goods into a wall or facia. It is used here also to mean connecting the various parts of the system together. A failure of this function may not impact the entire system function immediately but if not repaired it will cause future damage.

A description of the function of each element of the RWG system is as follows:

1. **Gutter:** to carry rainwater from roof surface to downpipe. The guttering must slope gently downwards in order to provide effective drainage.
2. **Gutter Union Bracket:** Connects two gutter pieces; some guttering ranges have joints already incorporated in the design.

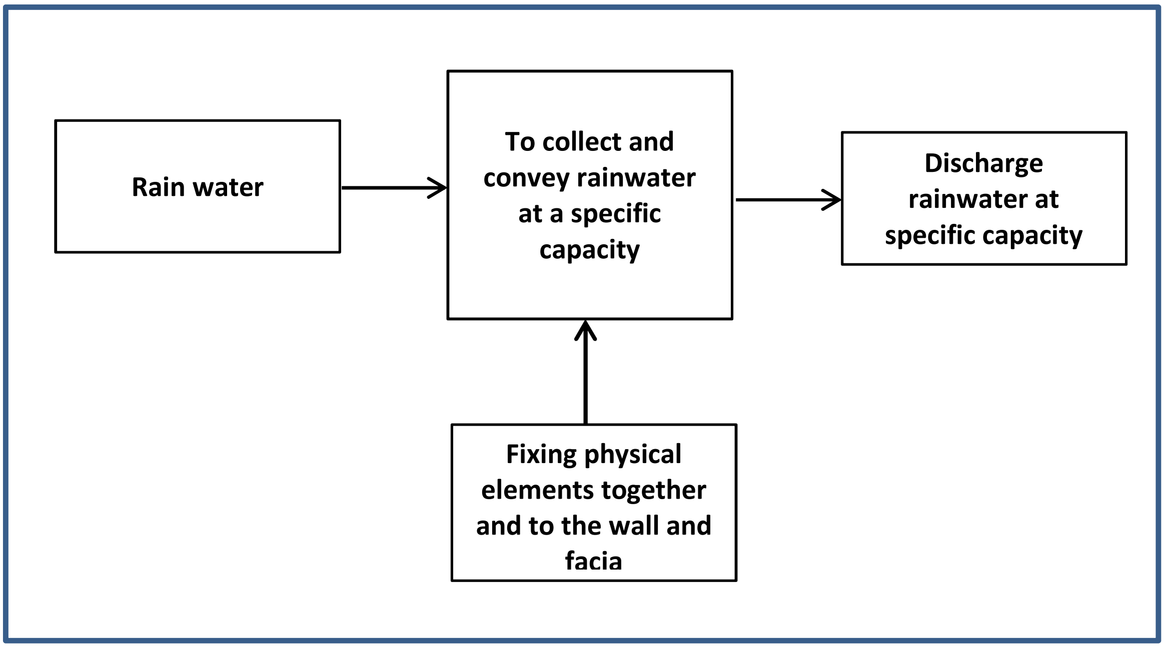

Figure 4:2 Rain Water Goods Functional model

3. **90° Gutter Angle:** Allows a run of guttering to continue around a corner.
4. **Stop End Outlet:** Sits at the end of a run of guttering to close the pipeline, and let water out by connecting to the downpipe.
5. **Hopper:** Funnel-shaped rainwater collector that diverts to a downpipe.
6. **Downpipe:** Lets water run down to the shoe.
7. **Downpipe Bracket:** Secures a downpipe to the wall.
8. **Shoe:** Fitted at the base of the downpipe to change the direction of the flow of water, discharging it horizontally clear of the wall, into a drain or a gully.
9. **Downpipe Connector:** Allows more than one downpipe to be connected in series.
10. **Branch:** Single branch for joining two downpipes together, to divert the water from another roof section into the same drain.
11. **Offset Bends:** these bends bring the downpipe close to the wall, ensuring water runs vertically, thus reducing debris build up.

12. **Running Outlet:** Provides an outlet to the downpipe for rainwater along the length of guttering.

13. **External Stop End:** Closes off a run of guttering.

14. **Gutter Support Bracket:** Attaches the guttering to the facia at 1m intervals.

4.2.1.3 *Cross mapping physical and functional models*

As described in section 3.2.2 each physical element within the system may perform one or more functions, and therefore to determine the effects of the failure of an element on the system's functionality, it is important to understand the relationship between the physical element and the functional model as described in Table 4.3.

Table 4:3 Cross mapping physical and functional models

No.	Physical Element	Function			
		Collecting	Fixing	Conveying	Discharging
1	Gutter	√		√	
2	Gutter Union Bracket	√	√	√	
3	Gutter Angle		√	√	
4	Stop End Outlet	√			√
5	External Stop End		√		
6	Running Outlet	√		√	√
7	Gutter Support Bracket		√		
8	Downpipe			√	√
9	Hopper	√			√
10	Shoe				√
11	Downpipe Connector			√	
12	Branch			√	
13	Offset Bends		√		
14	Downpipe Bracket		√		

4.2.2 Identifying Failure Modes

The FMEA analysis has identified 32 possible failure modes that could occur in a RWG system. A summary of the failure modes identified in the various elements of the RWG system is highlighted in Table 4.4. It should be noted that the same failure modes may occur on the various elements of the system, however, their causes and effects may differ depending on the function of the element.

Table 4:4 RWG Failure Modes

No.	Item/Element	Failure Modes
1	**Guttering**	Leaking water, Overflowing water, Fracture and cracking
2	**Gutter Union Bracket**	Leaking water, No proper connection of gutters
3	**Gutter Angle**	No proper connection of gutters, Leaking water
4	**Stop End Outlet**	Missing stop end, Not properly connected to the downpipe
5	**External Stop End**	Loose stop end, Missing stop end
6	**Running Outlet**	Overflowing water, Leaking water, No proper connection to gutters, Not properly connected to the downpipe
7	**Gutter Support Bracket**	Loss of fixing, Physical Damage, Defective support brackets
8	**Downpipes**	Leaking water, Fracture and cracking
9	**Hopper**	Overflowing water, Leaking water
10	**Shoe**	Insufficient discharge, Fracture and cracking, Loose shoe
11	**Downpipe Connector**	Loose connection
12	**Branch**	Leaking water
13	**Offset Bends**	Leaking water
14	**Downpipe Bracket**	Loss of fixing, Physical Damage, Defective support brackets

4.2.3 Identifying failure mode causes

The causes of the failure modes indicated in the previous section were identified. For example, the possible causes of water leaking from points along a gutter are sagging gutter due to inadequate support, wrongly positioned gutter, etc. The more accurate the description of the causes of failure, the easier it will be for tradesmen to decide how it may be eliminated or controlled. RWG Failure mode causes are summarised in Table 4.5.

Table 4:5 List of all RWG failure mode causes

Gutter	Downpipe
Sagging or twisted gutter sections	Blocked downpipe
Unsealed joints in gutter and between gutter outlet and downpipe	Displaced downpipe
Deterioration (ageing)	Joints are no longer effective
Faults of joints material	Lack of regular maintenance
Crazing or cracking	Water freezing to ice
Blockage or vegetation growth	Deterioration (ageing)
Misalignment of gutter sections	Physical impact
The provision of downpipes is not sufficient	Inadequate sealing
Heavy rain downpours	Blockage or vegetation growth
Water freezing to ice	Heavy rain downpours
Physical impact	Vandalism
Inadequate sealing	Crazing and cracking
Inadequately fixed to fascia and wall	Inadequately fixed to fascia and wall
Lack of regular maintenance	Wrong design
Vandalism	Poor workmanship
Wrong design	
Poor workmanship	

4.2.4 Identifying failure effects

Failure effects were discussed in section 3.2.5; the aim of this step is to identify what happens when each failure mode occurs. For example, two pieces of guttering may have the same type of failure mode but the effect of each failure will depend on where each piece is fitted. For the RWG system, the FMEA has identified that 21 failures had local, next higher and end effects; 27 failures had local and next higher effect and 24 failures had local effects only. The effect of individual failures is shown on the FMEA analysis sheet in Appendix A1.

It should be noted that the aim of any corrective action identified at the end of the analysis will be to overcome both the failure cause and the failure effect. Identification of the failure effect will provide evidence of the occurrence of failure and identify any threats to health and safety. Furthermore, identification of failure effects will play a role in determining the criticality of failure if and when Failure Mode Effects and Criticality Analysis (FMECA) is carried out. Criticality assessment will not be considered as part of this research as failure modes are used only to complete the RCM process and also because the research is concerned with applying FMEA qualitatively, criticality is a quantitative part of the analysis.

Having completed the FMEA analysis, the results are summarised in a FMEA table. Here the table tailored for use in the construction industry by the Construction Management Research Unit at the University of Dundee is used. The table is divided into six columns detailing: (1) Elements of the building system identified during the development of the physical model, (2) functions identified during the development of the functional model, (3) failure modes relevant to the element and its function, (4) failure mode causes, and (5) failure mode effects, the additional column indicating a corrective action is also included. The same failure mode may cause damage to a number of element functions and can generate other failure modes. Accordingly, in the FMEA table there is space to include as many lines as necessary to detail functions and failure modes. A sample of completed FMEA analysis of uPVC guttering is highlighted in Table 4.6. A full FMEA analysis of the RWG system is presented in Appendix A1.

Table 4:6 Sample FMEA of uPVC guttering

Id. No.	Item/Element Identification	Item/Element Function		Failure Modes		Failure Mode Causes	Failure Effects			Remarks
							LE	NHE	EE	
1.1	**Guttering**	To collect and convey rainwater from roof surface to downpipe	A	Leaking water	1	Sagging or twisted gutter sections	√	√	√	
					2	Unsealed joints in gutter and between gutter outlet and downpipe	√	√	√	
					3	Deterioration (ageing)	√	√		
					4	Faults of joints material	√			
					5	Crazing or cracking	√	√		
			B	Overflowing water	1	Blockage or vegitation growth	√	√	√	
					2	Misalignment of gutter sections	√	√		
					3	The provision of downpipes is not sufficient	√	√		
					4	Heavy rain downpours	√	√		
			C	Fracture and cracking	1	Water freezing to ice	√	√		
					2	Sagging or twisted gutter sections	√	√	√	
					3	Deterioration (ageing)	√	√		
					4	Physical impact	√			

4.3 Application of RCM

As previously indicated, RCM is about management of failures with the aim of preventing failures from occurring or reducing their effects to an acceptable level. The RCM decision logic process is designed to determine through the use of standard questions, what action should be taken to eliminate or reduce the consequences that result from the occurrence of a failure mode.

4.3.1 Identifying failure consequences

Identifying failure consequences was discussed in section 3.3.1. Using the decision logic process for identifying failure consequences as shown in Figure 3.7 the failure consequences for the RWG system were identified.

The following examples are used to illustrate how failure consequences are identified using the decision logic diagram.

Example 1-

Failure Mode	Failure Effect
Water leaking from points along the gutter	The effect of this is that the gutter may not be able to effectively convey rainwater leading to a loss of function, damage to the wall to which it is secured and if not adequately addressed damage to the building as a whole.

According to the decision logic diagram, the first test is whether the failure mode can be detected by the user/tenant. In this case the answer is yes, so clearly it is an evident failure. The next test is to whether it could have an adverse effect on the health or safety of the user/tenant which it clearly does not. The process continues to the next step which is to consider whether the cost of failure is greater than the cost of repairing it that is to consider the economic consequences. While the cost of repairing the failure might be low, it does not however, meet the cost effectiveness test given the limited loss of function. This indicates that the failure mode has appearance consequences. It could also be said that if no action is taken to address the failure, it could lead to economic and operational consequences. This represents an example of a failure mode with multiple consequences.

Example 2-

Failure Mode	Failure Effect
Running outlet not properly connected to the downpipe.	This failure mode is caused by unsealed joints between the gutter and downpipe. This could affect one of the functions of the running outlet which is to allow rainwater to discharge through the downpipe.

This failure mode will not be visible to the user/tenant as a result of build-up of water and therefore it is considered to be a hidden failure. It will not have health and safety consequences or economic consequences. It will however, have operational consequences as the whole system could be affected as a result.

Example 3 –

Failure Mode	Failure Effect
Overflow of water in hopper	This failure mode is caused due to the hopper becoming blocked due to build-up of dirt and leaves. This will lead to water that should be diverted to the downpipe to spill over.

This failure mode will be clearly visible to the user/tenant and therefore, it is an evident failure. It will not have any health and safety consequences; however, water pouring down from the hopper into the street will be unsightly which means that it has appearance consequences. If no timely action is taken to rectify the failure, it will lead to economic or operational consequences due to the onset of dampness.

A summary of RWG failure consequences is shown in Table 4.7.

Table4:7 Summary of RWG failure modes and their consequences

No.	Failure mode		Failure Consequences			
		H&S/E	Economic	Operational	Appearance	None
1	Leaking water				√	
2	Overflowing water		√	√	√	
3	Fracture and cracking of gutter					√
4	No proper connection gutters					√
5	Missing stop end				√	
6	Stop end outlet not properly connected to the downpipe					√
7	Loose stop end					√
8	Loss of fixing				√	
9	Physical Damage				√	
10	Running outlet not properly connected to the downpipe			√		
11	Blocked running outlet			√		
12	Defective support brackets					√
13	Insufficient discharge					√
14	Fracture and cracking of downpipe					√
15	Loose shoe				√	
16	Loose connection					√

4.3.2 Identifying maintenance tasks

Identifying maintenance tasks was discussed in section 3.3.2. Using the decision logic process highlighted in Figure 3.8 the maintenance tasks for the RWG system's failure modes were selected. The same examples used to illustrate failure mode consequences will be used to illustrate the identification of the most applicable and cost effective maintenance tasks.

Example 1-

In this case the failure mode was identified as having appearance consequences. The recommended maintenance task here according to the decision logic diagram is to carry out failure based maintenance in the form of sealing or replacing the affected parts.

Example 2-

Here the failure mode is evident and is identified to have operational consequences. The consideration here is to determine whether there is an applicable and cost effective condition based maintenance task that will prevent the failure or reduce its effect. The recommended action is therefore, to carry out a condition based task in the form of regular inspection of the seals between the running outlet and the downpipe. The CBM task is deemed to be both applicable and cost effective to avoid further failures with economic consequences.

Example 3-

Here the failure mode is evident and is identified to have appearance consequences. The recommended action is to carry out a failure based maintenance task, however, there is scope for regular inspects to be performed in order to easily prevent or reduce the effects of the failure mode.

A summary of the types of maintenance tasks selected for the RWG system is shown in Table 4.8.

Table 4:8 A summary of RWG Failure Modes and Related Maintenance Tasks

No.	Failure Mode	Maintenance Task	
		Failure Based Maintenance	Condition Based Maintenance
1	Leaking water	√	
2	Overflowing water	√	
3	Fracture and cracking of gutter		√
4	No proper connection to gutters		√
5	Missing stop end	√	
6	Stop end outlet not properly connected to the downpipe		√
7	Loose stop end		√
8	Loss of fixing	√	
9	Physical Damage	√	
10	Running outlet not properly connected to the downpipe	√	
11	Blocked running outlet	√	
12	Defective support brackets		√
13	Insufficient discharge		√
14	Fracture and cracking of downpipe		√
15	Loose shoe	√	
16	Loose connection		√

The results of the RCM analysis are recorded on the RCM decision table. In this case, the table developed by the Construction Management Research Unit at the University of Dundee was used. The table consists of seven columns detailing:

(1) the system item,

(2) the failure modes identified for each item,

(3) an indication whether the failure mode is hidden,

(4) the failure consequences whether health, safety, economic, operational, appearance or no consequence,

(5) the maintenance task identified whether failure based, time based, inspection based, no maintenance or re-design,

(6) the inspection method in the case of inspection based maintenance. These could be visual inspection, non-destructive testing or destructive testing as appropriate.

(7) Description of the actual maintenance task.

A sample of a RCM decision diagram for uPVC guttering is shown in Table 4.9. A full RCM analysis is presented in Appendix A2.

Table 4:9 Sample RCM Decision Diagram for RWG System

Id. No.	Item Identification	Failure Modes		Hidden failure	Failure Consequence						Maintenance Task					Inspection Method			Maintenance Task	Remarks
		Id. No.			HC	SC	EC	OC	AC	NC	FBM	TBM	IBM	NM	RD	VI	NDT	DT		
1.1	**Guttering**	A	Leaking water						√		√					√			Check seals and cracked parts, maintain or replace as necessary.	
		B	Overflowing water						√		√					√			Regular cleaning and flushing of gutters.	
		C	Fracture and cracking							√			√			√			Carry out regular inspections.	
1.2	Gutter Angle	A	No proper connection							√			√			√			Carry out regular inspections.	
		B	Leaking water						√		√					√			Check seals, maintain or replace affected parts.	
1.3	Stop End Outlet	A	Missing stop end						√		√					√			Replace as necessary.	
		B	No proper connection to the downpipe							√			√			√			Carry out regular inspections.	
1.4	External Stop End	A	Loose stop end							√			√			√			Carry out regular inspections.	
		B	Missing stop end						√		√					√			Replace as necessary.	
1.5	Running Outlet	A	Overflowing water						√		√					√			Regular cleaning and flushing of gutters.	
		B	Leaking water						√		√					√			Check seals, maintain or replace affected parts.	
		C	No proper connection							√			√			√			Carry out regular inspections.	
		D	No proper connection to the downpipe					√			√					√			Seal joints or replace affected parts.	
		E	Blocked outlet					√			√					√			Regular cleaning and flushing of gutters.	
1.6	Gutter Support Bracket	A	Loss of fixing						√		√					√			Maintain, re-affix bracket, replace nails as necessary.	
		B	Physical damage						√		√					√			Inspect and maintain as required.	
		C	Defective support brackets							√			√			√			Carry out regular inspections.	

4.4 Summary of Results

In considering the results of the case study, reference should be made to the full FMEA and RCM analysis in Appendix A1 & A2. To evaluate the results of the case study, a comparison between the results obtained from the historical repair data and the FMEA and RCM results was required. The basis for comparison was:

- The number of failure modes identified

- The number and type of the maintenance task selected

An evaluation of the results has indicated the following:

The successful application of FMEA and RCM is hugely dependent on expert judgement as problems may arise with the accuracy of identifying and describing failure modes. Accurate identification of failure modes represents the main challenge in the successful application of the techniques. Differences between the FMEA assumptions and the findings of the process can lead to some failure modes receiving more attention unnecessarily resulting in increased maintenance cost or insufficient attention that may lead to unnecessary risk.

The results indicated that the number of failure modes has increased as a result of applying FMEA and RCM as compared with failure modes identified from examining the historical repairs data. From data available on repairs to rainwater goods system from both data sources, it was established that there were 10 failure modes identified in the system. All these failure modes were repaired on the basis of a responsive maintenance strategy; there was no evidence of any preventive maintenance provision employed. The failure modes were:

Guttering	**Downpipe**
Leaking water	Displaced downpipe
Overflowing water	Leaking water
Physical damage	Overflowing water
Fracture and cracking	Physical damage
	Loose connection
	Fracture and cracking

The FMEA analysis has identified a total of 30 failure modes in the system. This represents an increase in the number of failure modes of 200%. All the failure modes identified were evident failures. Despite the increase in the number of failure modes, there are a number of failure modes that can be resolved by introducing basic mitigating measures. For example, out of a sample of 87 RWG repairs carried out by the data sources (Appendix A5), 33 repair tasks (38%) were related to blockages in the downpipe or guttering due to build-up of leaves and debris. These types of repairs could be avoided by a simple intervention such as placing a wire mesh over the guttering to minimise the build-up of leaves and/or regular cleaning and flushing of the system. It is noted however, that to ensure the cost effectiveness of such a strategy, a Cost Benefit Analysis is recommended.

As the function of the RWG system is to collect, convey and discharge rainwater effectively and safely away from the building it is not surprising that the dominant failure modes are related to leaking or over flowing water. This kind of failure mode usually affects the walls and facia to which the gutters and downpipes are secured. It is not surprising therefore that the RCM analysis has indicated that of the 30 failure modes identified, 16 had appearance consequences, 12 had no consequences, 2 had operational consequences, none had health and safety consequences, and none had economic consequences. Figure 4.3 indicates the failure consequences identified.

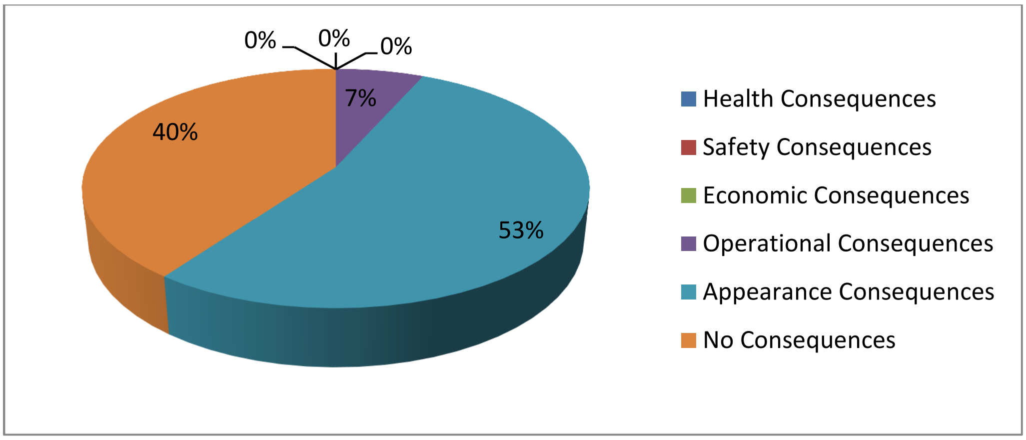

Figure 4:3 Analysis of RCM decision process for RWG failure consequences

The results have highlighted that reactive or failure based maintenance is the most applicable strategy for the majority of failure modes identified (60%) which may justify the strategy employed by the data sources in the maintenance of RWG. However, the application of RCM also indicated that 40% of the failure modes required condition based maintenance which is not currently applied. It is argued therefore, that if Condition Based Monitoring (CBM) is carried out where identified, the number, complexity and cost of Failure Based Maintenance (FBM) tasks will be reduced due to timely identification of failure modes. The RCM analysis has also identified that no failure modes required Time-Based Maintenance and none required re-design task as shown in Figure 4.4.

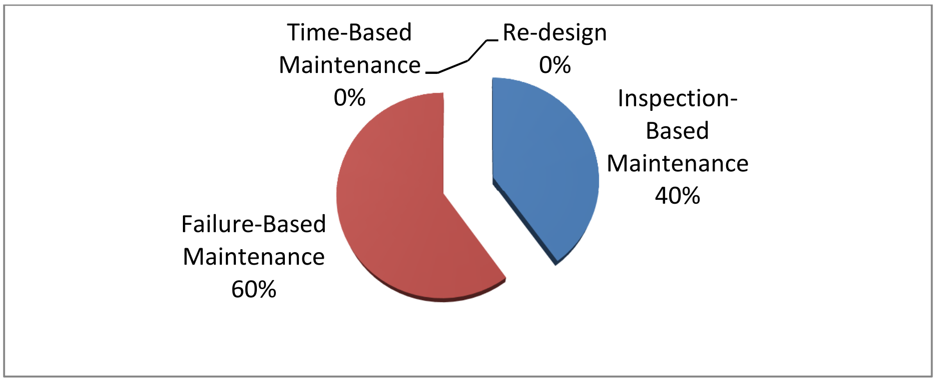

Figure 4:4 Analysis of RCM decision process for RWDS maintenance tasks

The subjective nature of RCM may not lend itself for application to all building elements or systems. This is particularly true when the same failure modes could have different consequences depending on the magnitude and context of failure.

4.5 Discussion and Conclusions

In general it has been shown that the application of Failure Modes Effects Analysis (FMEA) and Reliability Centred Maintenance (RCM) could provide an important methodology for failure analysis in the planning and scheduling of maintenance activities within building maintenance. The techniques make it possible to obtain a wide range of qualitative information such as failure modes descriptions, failure causes, effects and consequences that are useful for maintenance planning. The decision logic diagram provides clear direction for understanding maintenance needs and the actions that need to be taken to manage the consequences of failure.

The fragmented nature of building maintenance does not lend itself to effective implementation of RCM. Unlike other industries such as the aerospace, nuclear power and manufacturing, where failures are well defined and the boundaries for each failure mode is clearly identified, this does not apply within the construction industry in general and within building maintenance in particular. Within building maintenance failures are not generally well defined or understood. Failure effects and their consequences may differ from one building to another or from one location to another making any generalisation of maintenance practices a challenging and difficult process.

Some industries have critical systems that could have serious health, safety and environmental impact which could result in contravening national and international laws and regulations and the consequences of failure could be catastrophic. This is not the case within building maintenance. The reputational damage to an organisation as a result of serious accidents could be hugely significant as was the case with British Petroleum's oil spill in the Gulf of Mexico or NASA's loss of the Challenger Spacecraft. This linked to the economic impact as a result of loss of function due to operational failures means that these industries had to seek innovative and systematic tools such as RCM to prevent the occurrence of serious failures with significant consequences or reduce their effects should they occur. Within building maintenance, however, with the exception of mechanical and electrical installations, where the risk of any serious accident is minimal and the economic or operational consequences not as severe, a system as complicated and cumbersome as RCM to improve and optimise its maintenance strategies may not be needed.

Reference was made throughout the thesis to the pilot study conducted by El-Haram and Horner (2003) to implement ILS techniques to the maintenance of existing housing stock. This work successfully implemented FMEA and RCM and compared the results obtained to traditional maintenance practices. The results highlighted that savings of up to 18% could be realised. However, this was based on estimated costing of maintenance tasks identified as a result of applying the techniques and the tasks identified by the condition survey carried out prior to the application. There is therefore, no actual comparison to establish the nature and magnitude of the savings in order to justify the implementation of the techniques more widely. Similarly, in this research where the techniques were applied to the maintenance of a Rainwater Goods system, it was highlighted that the systematic nature of the process has identified failure modes, their causes, effects and consequences that may not have been known otherwise. However, it was not possible to measure the effect of such application to identify any real benefits other than making recommendations for possible mitigating measures to prevent or reduce the effects of some failures.

The application of FMEA and RCM are based on expert judgement for their effective implementation and require an investment in terms of time and resources. The application of RCM did not identify any health, safety, environmental or economic consequences. It is concluded therefore, that the application of a complicated system such as RCM or the investment required for such application within building maintenance in its entirety may not be justifiable. This is with the exception of mechanical and electrical installations where similarities may exist to other industries in terms of understanding failures and their consequences. Improvements to building maintenance provision could be realised by learning from applications of RCM in other industries and using the systematic thinking of the techniques to develop a simplified system for identifying maintenance requirements and optimising maintenance strategies as confirmed by identifying that 40% of the failure modes could benefit from CBM implementation. This linked to improvements to productivity of maintenance labour and resources by doing the right jobs at the right time in the right way could assist the industry to realise the goals of developing effective building maintenance strategies and ensuring cost effectiveness.

In the context of this research project, given that 60% of failure modes required responsive maintenance, while examining the productivity of labour in repair and maintenance operations, failure based (responsive, reactive) maintenance will be the focus for the remainder of this project.

Chapter 5: Factors affecting maintenance labour productivity

5.1 Introduction

The topic of construction productivity was reviewed in sections 2.9. Productivity was found to have a significant impact on the overall performance of the construction industry regardless of the size of organisation. There are a number of factors that have a direct effect on the productivity of labour, thus it is important for any organisation to identify those factors, understand their importance and take appropriate action for improving labour productivity.

Building maintenance and repair is considered as a labour intensive operation. Within building maintenance, many external and internal factors are never constant and are difficult to anticipate. This leads to continuous variation in labour productivity levels. Identification and evaluation of the factors affecting maintenance labour productivity can be hugely beneficial for those involved in the management of maintenance activities in order to improve productivity levels. Understanding the critical factors affecting productivity can be used to prepare a strategy to reduce inefficiencies, and to improve the effectiveness of maintenance performance.

This chapter discusses the findings of a survey questionnaire that has the objective of identifying the factors influencing maintenance labour productivity and to rank these factors in accordance with their importance.

5.2 Survey responses

The survey population included 29 Scottish local authorities, 60 UK Housing Associations and a sample of 15 maintenance contractors of which 28 responses were received representing 27% response rate, Breakdown of the responses is indicated in Table 7.2 . However, there were 7 responses that were not complete and therefore, the actual response rate was 20%. While the response rate was low, the responses were from a variety of organisations of varying sizes and approaches to maintenance work which provided a mixed representation of the industry, a breakdown of the respondent organisations is indicated in Table 5.2.

Table 5:2 Survey respondents

Organisation	No. Contacted	No. Responded	%
Local Authority	29	9	31%
Housing Association	60	12	20%
Maintenance Contractor	15	7	46%
Total	104	28	27%

The size of the 28 organisations that responded is indicated in Table 5.3.

Table 5:3 Indication of size of organisations responded

Number of maintenance personnel	%	Spend on maintenance or income generated	%
1 – 20	38.1	<1million	28.6
21 – 50	23.8	1 – 5 million	23.8
51 – 100	9.5	5 – 10 million	28.6
101 – 200	23.8	>10 million	19
200 +	4.8		
Total	**100**	**Total**	**100**

95.2% of the respondents indicated that they sub-contract parts of their maintenance work. A copy of the survey questionnaire is included in Appendix B1.

5.3 Ranking of the Factors

Once the factors influencing maintenance labour productivity were identified, the responses to the questionnaire were analysed in order to rank the factors according to their importance. For this purpose, the Importance Index method was used. This method was used successfully by other researchers to determine various aspects of importance of the factors influencing labour productivity in construction projects and within building maintenance (Kometa *et al*, 1994; Chan and Kumaraswamy, 1997; El-Haram and Horner, 2002; Alinaitwe et al, 2007; Jarkas and Bitar, 2012). For the purpose of ranking the factors, the possible responses to the survey questions were given numerical values as follows:

Very Important = 5, Important = 4, Somewhat Important = 3, Not Important = 2 and Don't Know = 1.

The factors were ranked by means of an importance index which was calculated as follows.

$$\sum_{i=1}^{5}(wi \text{ x } fxi) \text{ x } (100|5n) \qquad (11)$$

where:

wi = weight given to *ith* response;

i = 1, 2, 3, 4, or 5,

fxi = response frequency (fx1 = Don't know and fx5 = Very important); and

n = total number of responses (21 responses)

By way of example the calculation of the importance index for the 'the level of skill and motivation of workmen' factor is shown in Table 5.4.

Table 5:4 Calculation of the Importance Index for "level of skill and motivation of workmen"

Level of Importance	Weight *w*	Response Frequency *Fx*	*W* x *fx*
Very Important	5	16	80
Important	4	4	16
Somewhat Important	3	1	3
Not Important	2	0	0
Don't know	1	0	0
Total		**21**	**99**
Importance Index = 99 x 100/5x21 = 94.28			

All the factors were listed in descending rank order based on the importance index. The results are shown in Table 5.5.

Table 5:5 Ranking of Factors Affecting housing maintenance labour productivity

Rank	Factors	Importance Index
1	Level of skill and motivation of workmen	94
2	Quality of information, vague/incomplete work instructions	93
3	Labour turnover and absenteeism	90
4	Availability of tools and material	90
5	Access to the work site	88
6	Inconsistent, non-standard work methods, shortcuts or violations	84
7	Workers fatigue, stress, morale, sensory limitations	84
8	Unplanned errors and omissions, work stoppages, delays	80
9	Complexity and Scope of the work	79
10	Working hours	77
11	Continuity of work for the different trades	76
12	Weather conditions	70
13	The type of contract	67
14	Incentive scheme/performance related pay	50

5.3.1 Discussion of the factors

Maintenance labour productivity could be improved by carefully considering these factors and eliminating or mitigating their effect. It is assumed that the five highest ranking factors have the greatest impact on maintenance labour productivity in accordance with the 80/20 rule. The rationale behind the five highest ranking factors is discussed below.

1. Level of skill and motivation of workmen

Organisation	Very Important	Important	Somewhat Important	Not Important	Don't Know
Local Authority	71.4%	28.6%	0	0	0
Housing Association	77.8%	11.1%	11.1%	0	0
Maintenance Contractor	80%	20%	0	0	0

This factor was ranked highest among the survey respondents. Housing maintenance is a labour intensive activity and labour productivity is reliant on the skill and experience of the tradesmen. Lack of skill and/or low motivation could be considered as a major factor that could have serious impact on the time to complete a repair and maintenance task, the cost of labour and the quality of the finished work. Some trades such as electrical and plumbing work require specific skills and/or certification for tradesmen to be allowed to carry out related duties. If a tradesman without the required skill was allowed to carry out repair and maintenance tasks, the timely performance of the task would be affected and this would result in poor productivity or the potential risk of inferior quality of work. Similarly, low levels of motivation or the presence of demotivating factors are especially important in maintenance because the levels of supervision are low which may result in lower labour productivity.

2. Quality of information, vague/incomplete work instructions

Organisation	Very Important	Important	Somewhat Important	Not Important	Don't Know
Local Authority	57.1%	28.6%	0	14.3%	0
Housing Association	88.9%	11.1%	0	0	0
Maintenance Contractor	80%	20%	0	0	0

Ranked second among the factors, the quality of information and clear and complete work instructions are hugely important. It forms the basis on which the repair and maintenance work is planned, estimated and scheduled including determination of material requirements and the tradesman to carry out the repair. Furthermore, such information would typically include access information and other details relating to the work. Failure to provide complete and clear information and work instructions will have a serious impact on the performance of the job and will result in declined productivity.

This factor was not investigated as part of the analysis as the research is based on historical data. Furthermore, the process of reporting faults comes from the tenant who may not understand the nature of the failure. The initial data has indicated occasions when the extent of the work is greater than has been reported.

3. Labour turnover and absenteeism

Organisation	Very Important	Important	Somewhat Important	Not Important	Don't Know
Local Authority	71.4%	28.6%	0	0	0
Housing Association	44.4%	44.4%	11.1%	0	0
Maintenance Contractor	60%	40%	0	0	0

This third ranked factor is considered to be significantly important by maintenance managers. Allen (1985) stated that the main reason for the poor productivity of the construction industry was due to absences and unavailability of labour. High turnover and absences make it difficult for maintenance planners and supervisors to plan and allocate work effectively as they must adjust work schedules to accommodate missing tradesmen and/or not have enough tradesmen available to cover all the jobs planned. This will ultimately impact labour productivity.

4. Availability of tools and material

Organisation	Very Important	Important	Somewhat Important	Not Important	Don't Know
Local Authority	57.1%	42.9%	0	0	0
Housing Association	55.6%	33.3%	11.1%	0	0
Maintenance Contractor	60%	40%	0	0	0

With an importance index of 90, the survey respondents ranked availability of tools and material as the fourth factor influencing the productivity of housing maintenance and repair operations. A tradesman arriving at a job site without the right tools and/or materials will not be able to complete the allocated repair or maintenance task. This will lead to delays arising from the need to travel back to the depot to obtain the right tools and material or to order unavailable materials. This kind of delay can potentially impact the performance of the repair and maintenance work and will result in reduced productivity.

5. Access to the work site

Organisation	Very Important	Important	Somewhat Important	Not Important	Don't Know
Local Authority	42.9%	42.9%	14.3%	0	0
Housing Association	66.7%	22.2%	11.1%	0	0
Maintenance Contractor	60%	20%	0	20%	0

The fifth ranked factor affecting labour productivity in housing maintenance and repair operations is 'access to the work site'. A great deal of planning goes into scheduling repair and maintenance work; when a tradesman travels to a job only to find that access is not available, this causes a delay. Not only a second visit to the same job will be required, but also the tradesman's time is wasted at the expense of may be carrying out another job. This kind of delay affects labour productivity.

5.4 Attitudes to productivity improvement

The survey attempted to gauge the respondent's attitudes to productivity improvement within their organisations. Analysis of the responses indicated that 77% of the respondents measure labour productivity in relation to their maintenance activities. Among those, comparison of actual and estimated time to complete a repair was the favoured measurement method.

Asked how important is the issue of labour productivity on their list of managerial priorities, 58% of the respondents said that it is very important and 34% said it is an important priority for them. That said however, only 7% of the respondents indicated that their departments actually run any sort of productivity improvement initiative. The majority, 65% indicated that they do not. Among the productivity improvement initiatives identified by the respondents were:

- Improvement working groups, visits to other organisations to share good practice
- Review of employees performance measurement and Standard Minute Values (SMV)
- Use of tool box and operative talks to explain the proper use of coding and completing jobs
- Investment in new technology to assist the administration of the maintenance process and to capture important productivity data.

Asked to indicate to what extent do they agree or disagree with the statement "within our organisation there remains significant potential to improve maintenance labour productivity", 19% of the respondents said that they strongly agree and 50% said they agree.

5.5 Summary and Conclusions

This chapter has identified the factors that influence maintenance labour productivity and those factors were ranked according to their importance using an importance index. Improvement in labour productivity is achievable by focusing on mitigating the effects of the factors identified as influencing productivity, in particular the five highest ranked factors. Future research on the effect of each individual factor on labour productivity will provide an opportunity for predicting future maintenance costs.

While a great deal of research has been conducted to identify the factors affecting the productivity of labour in the construction industry, a review of the literature has found that no such attempt was conducted to identify factors affecting labour productivity in repair and maintenance operation. It is a contribution to knowledge to identify these factors and to rank them according to their importance. It is accepted that it would have been desirable to investigate the likelihood of occurrence of such factors to better understand the impact of each factor on productivity. However, due to limitations on data available, this was not possible and it is hoped that this could be taken up for future investigation.

On the attitudes to productivity improvement, it is concluded that labour productivity is a topic of importance to the majority of building maintenance organisations. While it appears to be measured and monitored, the majority of the respondents do not run any kind of productivity improvement initiative. This is despite the fact that the majority recognise that there is significant potential for improvement.

Chapter 6: Responsive Repairs Data Collection

6.1 Introduction

From the literature, it was found that until recently; most medium to large maintenance organisations such as Local Authorities and Housing Association have been using inadequate, outdated paper based recording systems. This is manifested by the unavailability of complete and accurate data relating to housing repair and maintenance. These systems were often maintained for the purpose of inputting financial information relating to repair and maintenance rather than systems that can be used to measure the performance of the operation including labour, material, equipment, scheduling etc.

The trend now is for such organisations to move towards using more sophisticated Computerised Maintenance Management Systems (CMMS). This is indeed the case with both the data sources one of which is currently using a CMMS system and the other is in the process of acquiring one. The main aspect of interest of such use for this study is the capture of the right data required to make decisions relating to labour productivity.

The objective of this chapter is to present the data available to carry out an analysis of maintenance labour productivity. The data required is available is described and the methodology for data collection from the data sources explained; this includes a description of the data preparation activities resulting in identifying the trades and repair tasks to be examined as part of the study.

6.2 Data Requirements

As the study relates to maintenance labour productivity, an evaluation of all aspects of a repair task that involve maintenance and repair tradesmen is necessary. The data needs to be comprehensive and capture the full range of parameters that might affect productivity, including an accurate description of the work, estimated times for a repair, actual repair times and a record of any delays and/or disruptions.

The data needs to cover a sufficiently long period of time so it is possible to observe trends in performance and to identify the range of factors that may impact labour productivity. Furthermore, the data needs to be complete and accurate in order to evaluate and understand the causes of variability so they may be addressed.

6.3 Sources of Data

For this study, there were two main sources of data:

- The Construction Division Repair and Maintenance Section, Dundee City Council
- Hillcrest Maintenance Services, The Hillcrest Group of Companies

Each of these data sources will be considered separately.

6.3.1 Construction Division Repair and Maintenance Section (CDRMS)

The Construction Division Repair and Maintenance Section is responsible for all maintenance repairs of the Council's housing stock, currently 13,000 units. The Housing Department and the Environment Department aim to provide an efficient and effective responsive repairs service, including programmed maintenance, small projects and maintenance of open spaces, to their tenants. Among the aims of the Responsive Repairs Department is to deliver the repairs service according to pre-determined specifications, budgets, timetable and quality standards.

6.3.2 Hillcrest Maintenance Services (HMS)

HMS describe themselves as a customer focused maintenance contractor who carries out a variety of responsive, void, cyclical, planned and property upgrade works for Hillcrest Housing Association and the Hillcrest Group of Companies as well as a number of external customers.

Hillcrest Housing Association was established in 1967 and is one of Scotland's largest Housing Associations. They provide housing and support in Dundee, Edinburgh, Angus, Perthshire and Fife, with over 5500 homes.

HMS provides an internal and external maintenance service competitively. They also provide a number of employment and training initiatives linked to their core business of maintenance.

With a team of over 100 tradesmen and support staff based in Dundee, they have easy access to all parts of Tayside, Fife, Edinburgh and Grampian, the areas where Hillcrest Housing Association properties are located. Prior to establishing the Hillcrest Maintenance Services, the housing association outsourced 100% of their repair and maintenance operations.

HMS tradesmen cover all aspects of Gas, Plumbing, Electrical, Joinery and Wet Trade works for Domestic and Commercial properties. HMS have recently launched Mobile Working Technology which offers a 'first contact appointment' system to all customers, with works invoiced electronically and real time progress available on any job. This is coupled with a work scheduling platform to offer a complete CMMS capable of recording and evaluating vital productivity related information.

6.4 Schedules of Rates

Schedules of Rates (SoR) are a list of prices, setting out how much a housing organisation will pay a contractor for different types of repair and maintenance work. Contractors use this as a basis for invoicing the housing provider. There are a number of versions of schedules of rates published by different organisations, these include:

- The PSA Schedules of Rates, published by the Stationary Office
- ORDB Schedule of Rates, published by RICS
- National Schedules, published by NSR Management

However, both data sources for this study use a variation of the M3NHF Schedule of Rates which is the Social Housing Industry Standard. This SoR "contains all that is required to specify repairs, enter into a measured term maintenance contract and control housing maintenance costs and quality". "It covers day-to-day and void repairs to social housing, contains both composite and elemental descriptions, is fully priced and compatible with all leading repairs ordering systems". www.m3h.co.uk/maintenance/m3-schedules/n (accessed Oct 14, 2015).

HMS is currently using a simplified version which totals approximately 80 codes for each of the trades under examination as part of this study. CDRMS on the other hand are loosely following the same SoR however, they also use historical data of similar repairs as an estimation basis for future work. Hence, there are differences in the data for estimations of value and duration of repairs. Table 6.1 shows a sample of SoR codes currently used by HMS.

Table 6:1 Sample SoR Codes used by HMS

Code	Vork Categor	sub-category	Priority (	Priority	Short	Uo	nit of Measureme	Rate	Time	Medium	Rate	Labour Rate	erial Rate	Total	k to zero	Travel Time	al Time	l Labour	l plus VAT	Total SoR
CAR001	Joiner	Fascias, Soffits and Bargeboards	R	Routine	FASCIA/SOFFIT/BARGE:RENEW OR REFIX SECTION	IT	per item	£54.64	90	Fascia/Soffit/Barge:Renew or refix fascia, soffit and/or barge ne 1.5 m long with treated softwood/wbp plywood, fix to roof timbers, remove/refix r.w. goods, cabling, adjust roof tiles,felt, decorate.	£26.26	£39.39	£15.25	£54.64	£0.00	30	120	£52.52	£18.30	**£70.82**
CAR003	Joiner	Flooring	U	Urgent	FLOORING:REFIX LOOSE TIMBER OR CHIPBOARD FLOORING	IT	per item	£37.13	60	Floorboard:Refix loose timber or chipboard flooring, including denail joists, remove waste and debris, punch in nails, level to existing and make good to existing finishes including any extra noggins required. Within any one room.	£26.26	£26.26	£10.87	£37.13	£0.00	30	90	£39.39	£13.04	**£52.43**
CAR005	Joiner	Flooring	R	Routine	FLOORING:RENEW TIMBER OR CHIPBOARD FLOORING	IT	per item	£112.91	90	Flooring:Renew any flooring with 19mm t&g, sq edge timber/flooring grade chipboard, denail joists, punch in nails, level to existing, additional noggins/support battens, make good to existing finishes. Within any one room.	£26.26	£39.39	£73.52	£112.91	£0.00	30	120	£52.52	£88.22	**£140.74**
CAR007	Joiner	External Cladding	R	Routine	CLADDING:REPAIR CLADDING OR BOARDING	IT	per item	£93.27	180	Cladding:Repair or minor renewal of timber or uPVC cladding or boarding including and repair or renewal of support framework and battens as required and make good to existing finishes decorations. In areas up to 5sm.	£26.26	£78.78	£14.49	£93.27	£0.00	30	210	£91.91	£17.39	**£109.30**
CAR009	Joiner	External Cladding	R	Routine	CLADDING:RENEW CLADDING OR BOARDING	IT	per item	£270.26	360	Cladding:Renew timber or uPVC cladding or boarding including and repair or renewal of support framework and battens as required and make good to existing finishes decorations. In areas up to 5sm.	£26.26	£157.56	£112.70	£270.26	£0.00	30	390	£170.69	£135.24	**£305.93**
CAR011	Joiner	Windows Renewals	R	Routine	WINDOW:RENEW TIMBER DG WINDOW	IT	per item	£611.38	270	Window:Renew any timber casement window to match existing style with cill, double glazed, weatherstripping, ironmongery, make good to existing finishes, decorate.	£26.26	£118.17	£493.21	£611.38	£0.00	30	300	£131.30	£591.85	**£723.15**
CAR013	Joiner	Windows Renewals	R	Routine	WINDOW:RENEW UPVC DG WINDOW	IT	per item	£603.05	180	Window:Renew any uPVC casement window to match existing style with cill, double glazed, weatherstripping, ironmongery, make good to existing finishes, decorate.	£26.26	£78.78	£524.27	£603.05	£0.00	30	210	£91.91	£629.12	**£721.03**
CAR015	Joiner	Windows Renewals	U	Urgent	WINDOW:RENEW FITTING TO TIMBER, METAL, PVC WINDOW	IT	per item	£24.53	30	Window:Renew any fitting to timber, metal or uPVC window including hinges, handles, stays, locks, espagnolettes, restrictors etc. Leave window in good working order.	£26.26	£13.13	£11.40	£24.53	£0.00	30	60	£26.26	£13.68	**£39.94**
CAR017	Joiner	Window Repairs	U	Urgent	WINDOW:REPAIR TIMBER WINDOW	IT	per item	£51.76	60	Window:Repair timber window or cill, cut out any rotten timber and splice in new section, ensure correct operation, ease and adjust openings and leave in good working order.	£26.26	£26.26	£25.50	£51.76	£0.00	30	90	£39.39	£30.60	**£69.99**
CAR019	Joiner	Window Repairs	U	Urgent	WINDOW:REPAIR UPVC WINDOW	IT	per item	£23.71	30	Window:Repair uPVC window or cill, ensure correct operation, lubricate fittings, repair or renew sealing gaskets, ease and adjust openings and leave in good working order.	£26.26	£13.13	£10.58	£23.71	£0.00	30	60	£26.26	£12.70	**£38.96**
CAR021	Joiner	Window Repairs	U	Urgent	WINDOW:REPAIR METAL WINDOW	IT	per item	£26.58	45	Window:Repair metal window, ensure correct operation, ease and adjust openings and leave in good working order.	£26.26	£19.70	£6.89	£26.58	£0.00	30	75	£32.83	£8.26	**£41.09**
CAR022	Joiner	Windows - Roof - Repairs	U	Urgent	ROOF WINDOW:REMEDY LEAK OR REDRESS FLASHINGS	IT	per item	£23.32	45	Roof Window:Redress roof flashings around roof window and reseal to prevent water penetration.	£26.26	£19.70	£3.63	£23.32	£0.00	30	75	£32.83	£4.35	**£37.18**
CAR023	Joiner	Door Renewals	R	Routine	DOOR:RENEW EXTERNAL TIMBER DOOR	IT	per item	£720.44	360	Door:Renew external door with any size 44mm hardwood panelled, glazed or part glazed door hang on 1.5 pair butts, fix ironmongery, weathermould, double glazed, make good to existing finishes, decorate to match existing.	£26.26	£157.56	£562.88	£720.44	£0.00	30	390	£170.69	£675.46	**£846.15**
CAR024	Joiner	Door Renewals	R	Routine	DOOR:HIGH PERFORMANCE FRONT OR BACK DOOR	IT	per item	£606.19	255	Door:Renew ext door with HP door, on 1.5 pr butts, fix mortice lock, door furniture, cut numerals, weathermld, ease/adjust, cut out,make good, rebate door bottom, fit waterbar, touch up, remove waste.	£26.26	£111.61	£494.59	£606.19	£0.00	30	285	£124.74	£593.50	**£718.24**
CAR025	Joiner	Door Renewals	R	Routine	DOOR:RENEW FIRE CHECK DOOR	IT	per item	£327.95	225	Door:Renew fire check door to match existing style and rating, hang new door on 1.5 pairs 100mm steel hinges, fix ironmongery, intumescent strips, smoke seals, make good to existing finishes, decorate to match existing.	£26.26	£98.48	£229.48	£327.95	£0.00	30	255	£111.61	£275.37	**£386.98**
CAR027	Joiner	Door Renewals	R	Routine	DOOR:RENEW INTERNAL DOOR	IT	per item	£233.67	180	Door:Renew internal door with any size or type to match existing, hang new door on 1 no. pair of 100mm steel butt hinges, all ironmongery, make good to existing finishes and decorate.	£26.26	£78.78	£154.89	£233.67	£0.00	30	210	£91.91	£185.87	**£277.78**
CAR029	Joiner	Door Renewals	R	Routine	DOOR:RENEW SHED / OUTHOUSE / STORE DOOR	IT	per item	£216.96	135	Door:Renew shed, outhouse or store door with any size softwood framed, ledged, braced door, 20mm tongued, grooved and v jointed boarding, including all ironmongery, decorate and make good to existing finishes.	£26.26	£59.09	£157.88	£216.96	£0.00	30	165	£72.22	£189.45	**£261.67**
CAR031	Joiner	Door Renewals	R	Routine	DOOR:RENEW UPVC DOOR AND FRAME	IT	per item	£634.64	210	Door:Renew any type door and frame with any size uPVC panelled/half glazed door, double glazed uPVC frame, prehung, compl. with multipoint locking system, handles, threshold weather seals, make good to existing finishes.	£26.26	£91.91	£542.73	£634.64	£0.00	30	240	£105.04	£651.28	**£756.32**
CAR033	Joiner	Door Repairs	R	Routine	DOOR:REPAIR TIMBER DOOR AND / OR RENEW FITTINGS.	IT	per item	£20.38	30	Door:Repair any fault to timber internal or external door. Check all fittings and ironmongery and repair or renew as required, ease and adjust door and leave in good working order.	£26.26	£13.13	£7.25	£20.38	£0.00	30	60	£26.26	£8.70	**£34.96**
CAR035	Joiner	Door Repairs	R	Routine	DOOR:REPAIR UPVC DOOR AND / OR RENEW FITTINGS.	IT	per item	£37.09	45	Door:Repair any fault to uPVC external door. Check all fittings and ironmongery and repair or renew as required, ease and adjust door and leave in good working order.	£26.26	£19.70	£17.40	£37.09	£0.00	30	75	£32.83	£20.87	**£53.70**
CAR037	Joiner	Door Repairs	R	Routine	DOOR:REPAIR OR RENEW SLIDING DOOR MECHANISM	IT	per item	£29.16	60	Door:Repair or renew sliding door mechanism for hanging of any internal door.	£26.26	£26.26	£2.90	£29.16	£0.00	30	90	£39.39	£3.48	**£42.87**

6.5 Data Collection

The data was collected from records of the Management Information System of the CDRMS. Data was also provided by HMS from their newly implemented CMMS. Both sets of data are described below.

6.5.1 Description of CDRMS Data

A sample of the raw data provided by CDRMS is in Table 6.2.

Table 6:2 Sample of Initial Data from CDRMS.

Description	Uow Key	Costcent	Total Committed	Total Billed	Material	Est Time	Ave.Cost	No.Jobs	Ave Hours
RENEW WALL TILES	600	R 0	5,835.31	9,075.88	2,148.97	3.75	211.07	43	3.99
RENEW FLOOR TILES	601	R 0	4,369.74	4,194.59	726.37	3.75	139.82	30	3.55
RENEW NON SLIP FLOORING	602	N 0	13,398.51	15,706.07	4,739.77	6.5	402.72	39	6.26
RENEW SLABS	1001	R 0	81,412.72	104,612.82	6,653.29	5	158.74	659	4.15
REPAIR FOOTPATH	1002	R 0	10,782.78	13,704.39	2,850.09	10	274.09	50	6.89
REPAIR/RENEW CLOTHES POLE	1003	R 0	18,404.94	24,511.68	6,336.46	2	100.46	244	2.16
BUILD UP FIREPLACE	1004	R 0	1,935.38	2,391.63	31.5	3	239.16	10	3
FILL/PATCH OR BRICK UP HOLE	1006	R 0	21,326.02	28,554.71	1,632.05	3.5	147.19	194	3.77
UNSAFE ACCESS PATH OR STEP (MAKE SAFE)	1008	E 0	3,243.67	8,045.12	146.54	4.5	134.09	60	4.17
ERECT SCAFFOLD AND AFTERWARDS STRIP	1400	R 0	3,399.67	1,449.51	0	10	144.95	10	4.62
CLEAR CHOKED DRAIN	1600	E 0	54,364.68	51,279.39	443.93	1	53.36	961	1.09
CLEAR CHOKED DRAIN	1600	E 10	12,137.55	9,212.28	12.9	1	41.68	221	1.01
REPAIR/RENEW DRAIN COVER	1601	Q 0	3,186.26	2,402.66	439.76	1	30.8	78	0.83
REPAIR/RENEW RAILINGS	1800	R 0	39,119.82	50,221.07	7,629.99	7	351.2	143	7.7
REPAIR METAL GATE	1801	R 0	23,523.25	27,827.23	2,690.57	4	160.85	173	4.16
SERVICE/EASE WINDOWS	1803	R 0	31,546.35	35,292.70	5,153.06	1.5	58.34	605	1.52
RENEW/REPAIR WINDOW FITTING	1804	R 0	57,800.16	62,062.85	11,330.10	1.25	54.2	1145	1.37
SECURE/MAKE SAFE WINDOW FITTING _ EMERGE	1806	E 0	26,620.63	27,964.94	4,214.30	1.25	51.98	538	1.35
FIT STEEL SCREENS	2000	Q 0	152.07	63.44	0	5	63.44	1	2
REMOVE STEEL SCREENS	2001	Q 0	94.35	332.07	0	2	332.07	1	4
FIT STEEL DOOR	2002	Q 0	631.62	610.61	0	4	67.85	9	2.13
REMOVE STEEL DOOR	2003	Q 0	1,121.85	1,686.32	5.16	2	52.7	32	1.65
REPAIR/RENEW GARAGE DOOR	2004	N 0	2,578.66	2,544.63	1,093.44	3	149.68	17	2.69
REPAIR/RENEW TIMBER GATE	2005	R 0	17,326.53	20,392.16	4,767.02	2.25	111.43	183	2.33
REPAIR/RENEW FLOOR BOARDS	2007	R 0	70,454.66	82,137.57	11,661.77	4	140.65	584	3.56
BARRICADE WINDOWS WITH PLYWOOD	2008	E 0	25,160.71	22,275.56	2,916.19	1	39.08	570	1.06
BARRICADE WINDOWS WITH PLYWOOD	2008	E 10	20,407.81	18,020.54	502.08	1	40.05	450	1.22

The initial data provided by CDRMS was a summary of maintenance activities for time periods, 2009/10 and 2010/11. The data consisted of a record of all responsive repairs carried out during the time periods. The raw data had the following headings:

1. Description – describing the actual repairs carried out
2. Cost Centre – this is a means of allocating costs.
3. Total Committed – this is the total amount allocated for each repair type

4. Total billed – this is the actual amount billed for the repair work carried out
5. Material – this is the total cost of material that was required to carry out the repairs
6. Estimated time – this forms part of the SoR system used by each of the data sources as indicated in section 6.4 and is the amount of time considered to be required to complete the repair work.
7. Average Cost – this is the average costs per job required to complete the repair work
8. Number of Jobs – this is the total number of jobs carried out during the time period
9. Average Hours – this is the actual average hours required to complete each repair work

Given the amount of data available for both time periods, it was necessary to sort the data in order to obtain a list of repairs that are significant in terms of cost and time and which have contributed the most to the overall cost and time requirements; Cost and Time Significance are discussed in chapter 3. Table 6.3 contains a summary of the key findings from the initial data:

Table 6:3Summary of Key Findings.

	2009/10	2010/11	% Change
Total Number of Repair Types	142	143	+ 0.7%
Total Amount Billed	£4,712,295	£5,133,211	+ 9%
Total Number of Repairs Carried Out	67,244	69,071	+ 3%
Total Man Hours Committed	113,917	112,560	- 1%

Initial efforts concentrated on identifying the cost and time significant items of repair. These are the few repair jobs that contributed the most to the overall expenditure and the time taken to repair. This was achieved by calculating the mean for both the total billed amount and the total time and from that only items that were equal to or higher than the mean were selected. The resultant list of repair items still contained a large number of items and further work was still required in order to narrow the range of repair items further. This was achieved through grouping similar repair items together, that is without consideration to whether the repair work was carried out on a routine or emergency basis.

The objective of the exercise described above is to arrive at a grouping of significant repair items from which to choose the trades and repair tasks that will be subject to the subsequent data analysis. A list of cost and time significant items emerged, 29 items during 2009/10 and 25 items during 2010/11 as shown on Table 6.4 and Table 6.5.

Table 6:4 Grouped TSI 2009/10

Grouped TSI 2009/10										
Description	Total Committed	Total Billed	Material	Est Time	Ave.Cost	No.Jobs	Ave Hours	Total Time	% Total Time	
RENEW SLABS	42,141.11	50,994.85	3,137.29	5	135.6	376	4.49	1,688	1%	Builder
REPAIR/RENEW RAILINGS	40,485.92	40,314.71	3,587.97	5.5	245.8	164	6.34	1,040	26%	**Joiner**
RENEW/REPAIR WINDOW FITTING	51,459.62	70,705.81	22,176.14	1.25	63.58	1112	1.48	1,646		
REPAIR/RENEW FLOOR BOARDS	99,792.23	100,143.96	10,757.05	4	116.5	860	3.52	3,027		
BARRICADE WINDOWS WITH & REMOVE PLYWOOD	47,944.15	45,696.95	4,326.73	3.5	187.7	1016	4.67	4,745		
EASE/REPAIR DOOR	75,265.66	104,241.42	11,577.10	2	66.65	1564	2.08	3,253		
SECURE/REMOVE BARRICADE FROM DOOR	32,721.95	40,283.60	3,140.79	2.5	130.2	920	4.09	3,763		
GAIN ENTRY FOR POLICE/TENANT	81,632.72	79,237.70	9,802.21	2	81.12	1959	2.31	4,525		
RENEW INTERNAL DOOR	69,524.06	93,574.92	25,560.11	4	176.2	531	4.51	2,395		
RENEW/REPAIR IRONMONGERY AND FITTINGS	153,451.62	184,425.51	24,461.50	3.5	131.6	4051	3.85	15,596		
RENEW PLASTERBOARD	120,489.66	125,734.01	8,746.13	6	328.3	383	6.44	2,467		
RENEW EXTERNAL DOOR	95,751.00	127,757.17	62,714.45	6	437.5	292	6.04	1,764		
		1,012,115.76	186850.18	40.25	1965	12852	45.33	44,220		
ROOF LEAKING - CARRY OUT REPAIR	31,506.40	30,487.42	153.4	4	132.7	490	4.34	2,127	3%	Roofer
REPAIR/RENEW TILES OR SLATES	104,404.61	104,523.78	647.55	3	260	402	5.96	2,396		
REPAIR RAINWATER GOODS AS DETAILED BELOW	46,994.51	42,638.04	1,284.75	4	131.6	324	3.45	1,118		
		177,649.24	2,085.70	11	524.3	1216	13.75	5,640		
REPAIR CISTERN	46,438.99	53,894.33	11,514.92	4	183.3	1153	4.1	4,727	35%	**Plumber**
CLEAR CHOKED DRAIN	84,261.08	75,267.48	378.79	2	97.53	1528	2.12	3,239		
REPAIR/RENEW TAPS	45,315.82	67,298.70	15,459.80	3	120.2	1350	3.3	4,455		
CLEAR CHOKE	48,201.45	46,390.76	1,014.48	2.5	72.15	1260	2.21	2,785		
REPAIR LEAK/BURST	251,815.15	250,147.16	16,747.81	2.5	86.78	5707	2.34	13,354		
REPAIR/RENEW/SERVICE GAS APPLIANCE	195,279.65	180,520.71	33,334.72	4.75	244.2	1976	4.51	8,912		
NO HEAT/HOT WATER	560,934.14	546,531.10	182,665.47	2	92.11	11787	1.93	22,749		
		1,220,050.24	261115.99	20.75	896.3	24761	20.51	60,221		
REPAIR/COMPLETE PLASTER	83,757.29	104,639.08	6,904.98	3	102.8	1018	3.28	3,339	2%	Plasterer
RENEW/REPAIR HEATER	92,806.80	76,367.33	32,407.05	4.5	275.4	732	4.7	3,440	21%	**Electrician**
CHECK ELECTRICS	177,436.08	161,743.89	12,378.27	2.5	81.36	3975	2.34	9,302		
STAIR LIGHTING/RENEW PENDANTS/SOCKETS	199,791.51	220,210.24	23,477.78	3.25	130.3	5333	3.88	20,692		
RENEW/REPAIR EXTRACTOR FAN	54,650.96	62,990.18	26,670.55	3.5	197.4	696	3.53	2,457		
		521,311.64	94933.65	13.75	684.5	10736	14.45	35,891		
REGLAZE & REPLACE PUTTY/SEALS	151,952.57	136,777.00	52078.4	12	675	1298	14.47	18,782	11%	Glazier
PAINT GENERAL SURFACES	34,744.76	43,528.04	3,827.48	3	96.94	449	3.16	1,419	1%	Painter

Table 6:5 Grouped TSI 2010/11

Grouped TSI 2010/11										
Description	**Total Committed**	**Total Billed**	**Material**	**Est Time**	**Ave.Cost**	**No.Jobs**	**Ave Hours**	**Total Time**	% Total Time	
RENEW SLABS	84,729.73	104,051.44	6,481.68	5	138.37	752	4.05	3,046	2.1%	Builder
RENEW/REPAIR WINDOW FITTING	55,577.81	58,480.51	9,091.55	1.25	48.98	1194	1.25	1,493	29%	**Joiner**
REPAIR/RENEW FLOOR BOARDS	73,181.69	75,621.64	8,410.32	4	120.42	628	3.18	1,997		
EASE/REPAIR DOOR	80,174.88	116,293.55	15,834.28	2	69.97	1662	1.92	3,191		
GAIN ENTRY FOR POLICE/TENANT	153,356.57	191,915.19	24,244.60	6	190.39	2290	5.1	11,679		
RENEW INTERNAL DOOR	53,947.86	77,858.11	21,151.45	4	189.44	411	4.43	1,821		
RENEW/REPAIR IRONMONGERY AND FITTINGS	178,229.64	209,207.06	29,601.19	3.5	129.71	4759	3.55	16,894		
RENEW PLASTERBOARD	107,117.88	130,596.88	8,165.16	6	385.24	339	6.49	2,200		
RENEW EXTERNAL DOOR	118,570.45	172,936.83	86,933.66	6	479.05	361	5.93	2,141		
		1,032,909.77	203,432.21	32.75	1613.2	11644	31.85	41,416		
ROOF LEAKING - CARRY OUT REPAIR	30,556.75	29,297.33	524.16	2	61.68	475	1.89	898	5%	Roofer
PATCH ROUGHCAST	30,107.59	34,376.07	723.09	2.5	205.84	167	4.8	802		
REPAIR/RENEW TILES OR SLATES	146,208.63	145,801.84	1,269.90	3	303.12	481	7.29	3,506		
REPAIR RAINWATER GOODS AS DETAILED BELOW	86,397.06	102,707.84	2,857.47	4	209.18	491	4.66	2,288		
		312,183.08	5,374.62	11.5	779.82	1614	18.64	7,494		
CLEAR CHOKED DRAIN	71,399.01	63,491.62	125.86	1	50.31	1262	1.01	1,275	36%	**Plumber**
REPAIR/RENEW TAPS	45,367.79	69,362.03	12,617.70	1	51.88	1337	1.26	1,685		
CLEAR CHOKE	42,870.33	47,423.07	980.08	1.25	42.65	1112	1.23	1,368		
REPAIR LEAK/BURST	281,731.51	304,840.52	14,489.79	2.5	95.16	6334	2.4	15,202		
REPAIR/RENEW RADIATOR	69,953.25	67,495.24	6,625.84	1.5	60.21	1121	1.46	1,637		
REPAIR/SERVICE GAS APPLIANCE	180,022.95	167,510.42	39,957.00	2.75	188.3	2034	2.98	6,061		
NO HEAT/HOT WATER	572,855.46	599,306.00	199,908.72	2	99.21	12002	1.97	23,644		
		1,319,428.90	274,704.99	12	587.72	25202	12.31	50,871		
REPAIR/COMPLETE PLASTER	108,599.18	121,409.41	7,489.10	11	332.62	1039	9.6	9,974	7%	Plasterer
CHECK ELECTRICS	185,265.00	179,890.57	19,133.53	2.5	86.21	4140	2.34	9,688	19%	**Electrician**
STAIR LIGHTING/RENEW PENDANTS/SOCKETS	183,138.32	217,050.05	31,343.58	3.25	136.95	4874	3.54	17,254		
		396,940.62	50,477.11	5.75	223.16	9014	5.88	26,942		
REGLAZE WITH D.G. UNITS(CRACKED)	59,564.63	68,966.51	32,602.41	2	136.03	507	2.2	1,115	1%	Glazier
PAINT GENERAL SURFACES	43,060.44	49,746.07	4,627.22	3	88.52	562	2.61	1,467	1%	Painter

6.5.2 CDRMS Data Preparation

In order to gather the necessary data, CDRMS gave the researcher temporary access to the CDRMS maintenance records database The data was made available in a word document format; a sample of the data is shown in Table 6.6 This data needed to be converted into a format that would assist the data analysis process. Initially data for a single period (January 2013) was available; however, potentially the researcher was faced with the painstaking and time consuming task of manually converting over 1500 billing records into an excel spreadsheet. As a result, an IT expert was commissioned to convert the records to a suitable format. The data was captured under the headings: Job Number, Property Address, Description, Total Value, Material Cost, Labour Cost, Tradesman.

Having calculated the 'actual time' as highlighted in Section 3.10.5**,** and given that estimated times for the various repair tasks were available from the initial data, it was possible to begin the data preparation stage.

Following the analysis of the January 2013 set of data, it became clear that data for a single time period may not be sufficient to represent all the potential variables, especially any seasonal variability in productivity. Additional data for time periods April 2013, June 2013, September 2013 and November 2013 was therefore obtained from CDRMS. The opportunity was also taken to include further data that was deemed useful as a result of the analysis of the January 2013 data, including the Benchmark value (estimated value), Allocation date, Target date, Completion date. A sample of the complete dataset is shown in Table 6.7.

Table 6:6Sample of Billing Record from CDRMS

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BILLING INFORMATION      Week Ending 25 JAN 2013
                               MINOR DISADAPTATION - Cost Centre 1013

JOB NUM   K73174    AREA  -  2   , 1 ARKLAY PLACE DUNDEE                            DATE ALLOCATED


Ledger    H9092/82716           9008      WOOD THRESHOLD X2. REMOVE                   TARGET DATE     01/05/2012
                                          EXISTING AND REPLACE WITH LEVEL METAL ONES AT

LABOUR    DOCUMENTS                       MEN                                          VALUE  COMPLETED DATE  30/04/2012
          234222                          2035                                         31.72
          234265                          2035                                         47.58

                  TOTAL LABOUR VALUE                                                   79.30


MATERIALS

                  TOTAL MATERIALS VALUE                                                 6.48

                  TOTAL BILLED                                                         85.78  BENCH MARK VALUE     65.00


BILLING INFORMATION      Week Ending 25 JAN 2013
                               REPAIRS & MAINTENANCE  - Cost Centre 1000

JOB NUM   K76441    AREA  -  4   , 20 CRAIGIELEA PLACE DUNDEE                               DATE ALLOCATED  09/05/2012


Ledger    H6940/11100           4410      NEW BOILER REQD AS PER K75393                        TARGET DATE     24/05/2012
                                          P.GARNETT

LABOUR    DOCUMENTS                       MEN                                          VALUE  COMPLETED DATE  21/01/2013
          235637                          4089                                        165.80
          235465                          6047                                         99.48

                  TOTAL LABOUR VALUE                                                  265.28
```

Table 6:7 Sample of Responsive Repairs Data

Job No.	Address	Description	Total Value	Material cost	Bmark Value	Labour Cost	Billed Time	No. of Men	Tradesman	Date Allocated	Target Date	Completed Date
L59053	8 BALCARRES TERRACE DUNDEE	Repair Radiator	£33.16	£0.00	£90.00	£33.16	2	1	4017	22/01/2013	28/01/2013	22/01/2013
L36220	14 ORRIN PLACE DUNDEE	Repair Radiator	£51.90	£0.00	£90.00	£51.90	3	6	44,104,423	14/11/2012	21/11/2012	23/11/2012
L36652	133 BALUNIE DRIVE DUNDEE	Repair Radiator	£51.90	£0.00	£90.00	£51.90	3	2	4410,4410	27/11/2012	22/12/2012	12/12/2012
L46198	16 BALLANTRAE ROAD DUNDEE	Repair Radiator	£8.65	£0.00	£90.00	£8.65	0.5	1	4405	19/12/2013	19/12/2013	01/01/2013
L47535	141 CRAIGIE DRIVE DUNDEE	Repair Radiator	£8.65	£0.00	£58.96	£8.65	0.5	1	4405	18/12/2012	07/01/2013	02/01/2013
L55074	25 KEMNAY GARDENS DUNDEE	Repair Radiator	£51.35	£18.19	£90.00	£33.16	2	1	4028	14/01/2013	17/01/2013	17/01/2013
L57327	73 CRAIGOWAN ROAD DUNDEE	Repair Radiator	£33.16	£0.00	£90.00	£33.16	2	1	4009	21/01/2013	23/01/2013	21/01/2013
L56493	16 CORSO STREET DUNDEE	Repair Radiator	£33.16	£0.00	£90.00	£33.16	2	1	4009	21/01/2013	22/01/2013	21/01/2013
L58435	21 DIGHTY GARDENS DUNDEE	Repair Radiator	£33.16	£0.00	£90.00	£33.16	2	1	4009	21/01/2013	25/01/2013	21/01/2013
L53172	44 BALGARTHNO ROAD DUNDEE	Repair Radiator	£34.60	£0.00	£58.96	£34.60	2	2	4407,4425	09/01/2013	28/01/2013	22/01/2013
L45065	3 GOURDIE STREET DUNDEE	Repair Radiator	£43.25	£0.00	£58.96	£43.25	2.5	3	44,254,423	03/01/2013	31/01/2013	22/01/2013
L59216	60 BALUNIE AVENUE DUNDEE	Repair Radiator	£66.32	£0.00	£90.00	£66.32	4	1	4017	22/01/2013	28/01/2013	22/01/2013
L57564	25 GLENPROSEN TERRACE DUNDEE	Repair Radiator	£25.95	£0.00	£58.96	£25.95	1.5	2	4410,4423	17/01/2013	07/02/2013	22/01/2013
L58935	16 ST. NINIAN TERRACE DUNDEE	Repair Radiator	£17.30	£0.00	£58.96	£17.30	1	1	4404	22/01/2013	13/02/2013	23/01/2013
L60235	135 TWEED CRESCENT DUNDEE	Repair Radiator	£17.30	£0.00	£35.97	£17.30	1	1	4407	23/01/2013	24/01/2013	23/01/2013
L58516	8 FINLARIG TERRACE DUNDEE	Repair Radiator	£24.87	£0.00	£90.00	£24.87	1.5	1	4028	22/01/2013	28/01/2013	23/01/2013
L50542	7 LONGHAUGH TERRACE DUNDEE	Repair Radiator	£34.60	£0.00	£58.96	£34.60	2	2	4402,4402	09/01/2013	17/01/2013	23/01/2013
L52991	56 COURT STREET NORTH DUNDEE	Repair Radiator	£17.30	£0.00	£58.96	£17.30	1	1	4412	15/01/2013	28/01/2013	23/01/2013

6.5.3 Description of HMS Data

The data provided by HMS in a spread sheet format was complete and was collected using up-to-date technology. However, the way it was presented was not suitable for it to be immediately usable. In order to collate the required data, it was necessary to work with three separate spread sheets simultaneously to collect all the data on a single spread sheet so that the data could be sorted in a way that allowed the performance of the necessary analysis.

Table 6.8 Highlights the data presented in the various spread sheets and the headings that were of interest among them.

There was very little useful information in the 'Order Header' sheet so the majority of data was obtained from the other two sheets. This was accomplished by sorting the data according to the tradesman ID which was common between the 'Appointments' and the 'Order Detail' sheets, allowing the required data to be combined into a single spread sheet.

Table 6:8 HMS Data Headings

No.	ORDER HEADER		APPOINTMENTS		ORDER DETAIL	
1	Order Number	☑	Order Number	☑	Order Number	☑
2	Property ID		Job ID		Trade	
3	Property Address	☑	Appointment Number		SoR Description	☑
4	Order Description		Completed Date	☑	SoR Status	
5	Final Order Value		Job Complete (y, N)		Quantity	
6	Initial Order Value		Incomplete Reason		SoR Value	
7	Issue Date		Operative ID	☑	SoR SMV (est time)	☑
8	Priority Description		Travel Time	☑	Total Value	
9	Month Issued		Risk Assessment Time	☑	Completed by	☑
10	Year Issued		Repair Time	☑		
11			Week Day	☑		

The data was then partitioned according to the trades and then using the trades' data it was partitioned further according to the various tasks. Table 6.9 shows a sample of the combined data ready for analysis.

Table 6:9 Sample complete HMS Data Sheet

Order Number	SoR Description	Total Value	SoR Est SMV	Est. Time (hours)	Total Time (hours)	Total Time	PI EH	Operative ID	Travel Time	Risk Assess Time	Repair Time	Week Day	SoR Code	Completed Date
366797	THRESHOLD:RENEW OR REFIX TO DOOR OPENING	31.38	50	0.83333	1.32	01:19:26	0.63	MCF012	00:15:14	00:17:25	00:46:47	Thursday	CAR084	28/11/2013 09:09
367803	WEATHERSTRIP/DRAUGHTPROOF:RENEW OR REFIX STRIPS	63.21	50	0.83333	1.52	01:31:39	0.55	MCF012	00:14:22	00:03:35	01:13:42	Thursday	CAR103	28/11/2013 12:27
367868	THRESHOLD:RENEW OR REFIX TO DOOR OPENING	31.38	50	0.83333	0.95	00:57:01	0.88	LEE003	00:19:56	00:05:55	00:31:10	Monday	CAR084	25/11/2013 14:07
367953	DOOR:REPAIR UPVC DOOR AND / OR RENEW FITTINGS.	53.7	75	1.25	0.38	00:23:01	3.29	MCF012	00:05:34	00:10:00	00:07:27	Monday	CAR035	25/11/2013 16:19
368033	FRAME:REPAIR EXTERNAL DOOR FRAME	100.05	75	1.25	2.9	02:54:07	0.43	LEE003	00:12:17	00:10:13	02:31:37	Monday	CAR047	02/12/2013 11:12
368151	DOOR:REPAIR TIMBER DOOR AND / OR RENEW FITTINGS.	34.96	50	0.83333	0.65	00:39:28	1.28	MCF012	00:03:38	00:00:43	00:35:07	Thursday	CAR033	28/11/2013 10:36
368179	DOOR:REPAIR TIMBER DOOR AND / OR RENEW FITTINGS.	34.96	50	0.83333	2.13	02:08:23	0.39	LEE003	00:00:10	00:25:16	01:42:57	Wednesday	CAR033	27/11/2013 10:39
368179	DOOR:REPAIR TIMBER DOOR AND / OR RENEW FITTINGS.	34.96	50	0.83333	1.33	01:20:08	0.63	LEE003	00:50:43	00:00:22	00:29:03	Wednesday	CAR033	27/11/2013 16:19
368190	DOOR:REPAIR TIMBER DOOR AND / OR RENEW FITTINGS.	34.96	50	0.83333	0.83	00:50:41	1.00	MCF012	00:12:11	00:02:32	00:35:58	Wednesday	CAR033	27/11/2013 15:14
368260	DOOR:REPAIR TIMBER DOOR AND / OR RENEW FITTINGS.	209.76	50	0.83333	2.38	02:23:16	0.35	MCF012	00:13:17	00:01:47	02:08:12	Monday	CAR033	02/12/2013 10:15
368284	DOOR:REPAIR TIMBER DOOR AND / OR RENEW FITTINGS.	34.96	50	0.83333	0.97	00:58:36	0.86	LEE003	00:05:03	00:14:18	00:39:15	Thursday	CAR033	28/11/2013 16:30
368311	DOOR:REPAIR TIMBER DOOR AND / OR RENEW FITTINGS.	34.96	50	0.83333	0.38	00:23:17	2.19	MCF012	00:09:41	00:02:20	00:11:16	Thursday	CAR033	28/11/2013 16:12
368387	DOOR:REPAIR TIMBER DOOR AND / OR RENEW FITTINGS.	34.96	50	0.83333	1.05	01:03:11	0.79	MCF012	00:19:26	00:00:54	00:42:51	Thursday	CAR033	28/11/2013 14:42
368414	DOOR:REPAIR TIMBER DOOR AND / OR RENEW FITTINGS.	34.96	50	0.83333	1.53	01:32:47	0.54	LEE003	00:21:12	00:01:02	01:10:33	Friday	CAR033	29/11/2013 10:46
368493	WEATHERSTRIP/DRAUGHTPROOF:RENEW OR REFIX STRIPS	63.21	50	0.83333	0.27	00:16:59	3.09	TRE002	00:15:18	00:00:15	00:01:26	Friday	CAR103	29/11/2013 15:00
368536	DOOR:REPAIR TIMBER DOOR AND / OR RENEW FITTINGS.	34.96	50	0.83333	1	01:00:27	0.83	LEE003	00:06:15	00:39:36	00:14:36	Tuesday	CAR033	10/12/2013 12:28
368551	DOOR:REPAIR TIMBER DOOR AND / OR RENEW FITTINGS.	34.96	50	0.83333	2.2	02:12:48	0.38	TRE002	00:23:56	00:22:54	01:25:58	Wednesday	CAR033	22/01/2014 10:57
368555	DOOR:REPAIR TIMBER DOOR AND / OR RENEW FITTINGS.	34.96	50	0.83333	2.62	02:37:17	0.32	MCF012	00:07:51	00:00:19	02:29:07	Monday	CAR033	02/12/2013 15:31
368573	DOOR:REPAIR TIMBER DOOR AND / OR RENEW FITTINGS.	34.96	50	0.83333	0.43	00:26:01	1.94	MCF012	00:08:22	00:01:12	00:16:27	Monday	CAR033	02/12/2013 16:43
368595	DOOR:REPAIR TIMBER DOOR AND / OR RENEW FITTINGS.	34.96	50	0.83333	0.42	00:25:25	1.98	LEE003	00:00:05	00:00:19	00:25:01	Thursday	CAR033	05/12/2013 09:04
368763	WEATHERSTRIP/DRAUGHTPROOF:RENEW OR REFIX STRIPS	252.84	50	0.83333	1.8	01:48:45	0.46	MCF012	00:16:50	00:05:44	01:26:11	Wednesday	CAR103	18/12/2013 15:05
368894	DOOR:REPAIR TIMBER DOOR AND / OR RENEW FITTINGS.	34.96	50	0.83333	1.73	01:44:51	0.48	TRE002	00:05:23	00:01:28	01:38:00	Wednesday	CAR033	04/12/2013 13:10
368912	DOOR:REPAIR TIMBER DOOR AND / OR RENEW FITTINGS.	34.96	50	0.83333	1.93	01:56:28	0.43	MCF012	00:16:35	00:06:23	01:33:30	Monday	CAR033	16/12/2013 10:14
369405	DOOR:REPAIR TIMBER DOOR AND / OR RENEW FITTINGS.	34.96	50	0.83333	0.35	00:21:29	2.38	MCF012	00:03:55	00:01:39	00:15:55	Monday	CAR033	09/12/2013 11:34
369106	DOOR:REPAIR TIMBER DOOR AND / OR RENEW FITTINGS.	34.96	50	0.83333	1.18	01:11:15	0.71	LEE003	00:04:46	00:12:00	00:54:29	Monday	CAR033	09/12/2013 16:13
369100	WEATHERSTRIP/DRAUGHTPROOF:RENEW OR REFIX STRIPS	126.42	50	0.83333	0.9	00:54:26	0.93	MCF012	00:15:18	00:04:48	00:34:20	Tuesday	CAR103	10/12/2013 09:24
369309	DOOR:REPAIR TIMBER DOOR AND / OR RENEW FITTINGS.	34.96	50	0.83333	0.68	00:41:54	1.23	LEE003	00:19:48	00:07:42	00:14:24	Tuesday	CAR033	10/12/2013 09:28
369506	DOOR:REPAIR TIMBER DOOR AND / OR RENEW FITTINGS.	34.96	50	0.83333	1.17	01:10:11	0.71	MCF012	00:16:30	00:15:57	00:37:44	Tuesday	CAR033	10/12/2013 10:50
368536	DOOR:REPAIR TIMBER DOOR AND / OR RENEW FITTINGS.	34.96	50	0.83333	1	01:00:27	0.83	LEE003	00:06:15	00:39:36	00:14:36	Tuesday	CAR033	10/12/2013 12:28
369580	DOOR:REPAIR TIMBER DOOR AND / OR RENEW FITTINGS.	34.96	50	0.83333	1.88	01:53:08	0.44	MCF012	00:25:54	00:59:59	00:27:15	Tuesday	CAR033	10/12/2013 14:18
369314	DOOR:REPAIR TIMBER DOOR AND / OR RENEW FITTINGS.	34.96	50	0.83333	2.03	02:02:54	0.41	LEE003	00:13:41	00:45:45	01:03:28	Tuesday	CAR033	10/12/2013 17:34
369265	DOOR:REPAIR TIMBER DOOR AND / OR RENEW FITTINGS.	69.92	50	0.83333	1.25	01:15:45	0.67	TRE002	00:08:49	00:01:17	01:05:39	Wednesday	CAR033	11/12/2013 11:11
369718	DOOR:REPAIR TIMBER DOOR AND / OR RENEW FITTINGS.	69.92	50	0.83333	2.62	02:37:48	0.32	LEE003	00:09:19	00:37:14	01:51:15	Thursday	CAR033	12/12/2013 15:57
369603	DOOR:REPAIR TIMBER DOOR AND / OR RENEW FITTINGS.	34.96	50	0.83333	0.63	00:38:44	1.32	MCF012	00:00:12	00:02:32	00:36:00	Friday	CAR033	13/12/2013 13:20
368912	DOOR:REPAIR TIMBER DOOR AND / OR RENEW FITTINGS.	34.96	50	0.83333	1.93	01:56:28	0.43	MCF012	00:16:35	00:06:23	01:33:30	Monday	CAR033	16/12/2013 10:14
369198	WEATHERSTRIP/DRAUGHTPROOF:RENEW OR REFIX STRIPS	63.21	50	0.83333	0.85	00:51:09	0.98	TRE002	00:10:53	00:38:41	00:01:35	Monday	CAR103	16/12/2013 16:18
370100	DOOR:REPAIR TIMBER DOOR AND / OR RENEW FITTINGS.	34.96	50	0.83333	0.37	00:22:08	2.25	LEE003	00:15:44	00:03:16	00:03:08	Tuesday	CAR033	17/12/2013 11:17
369907	WEATHERSTRIP/DRAUGHTPROOF:RENEW OR REFIX STRIPS	63.21	50	0.83333	1.7	01:42:34	0.49	LEE003	00:23:50	00:06:42	01:12:02	Tuesday	CAR103	17/12/2013 13:12
370143	DOOR:REPAIR TIMBER DOOR AND / OR RENEW FITTINGS.	34.96	50	0.83333	0.45	00:27:55	1.85	LEE003	00:09:47	00:15:54	00:02:14	Tuesday	CAR033	17/12/2013 15:40
368763	WEATHERSTRIP/DRAUGHTPROOF:RENEW OR REFIX STRIPS	252.84	50	0.83333	1.8	01:48:45	0.46	MCF012	00:16:50	00:05:44	01:26:11	Wednesday	CAR103	18/12/2013 15:05
370338	DOOR:REPAIR TIMBER DOOR AND / OR RENEW FITTINGS.	34.96	50	0.83333	1.37	01:22:02	0.61	MCF012	00:12:42	00:00:23	01:08:57	Thursday	CAR033	19/12/2013 09:09
369916	DOOR:REPAIR TIMBER DOOR AND / OR RENEW FITTINGS.	34.96	50	0.83333	0.6	00:36:54	1.39	TRE002	00:09:02	00:26:22	00:01:30	Friday	CAR033	20/12/2013 13:54
370550	DOOR:REPAIR TIMBER DOOR AND / OR RENEW FITTINGS.	34.96	50	0.83333	0.92	00:55:13	0.91	TRE002	00:10:27	00:02:17	00:42:29	Monday	CAR033	23/12/2013 10:53

6.6 Summary and Conclusions

This chapter can be summarised as follows:

1. Data was collected from two maintenance and repair organisations responsible for maintaining properties of two major social landlords. One of the organisations is a Local Authority, the other is a Housing Association.

2. The data provided was collected using a basic in-house system in the case of CDRMS and using a sophisticated mobile working and work scheduling system in the case of HMS.

3. Data from both organisations had to be re-formatted to make it suitable for analysis.

4. One of the most vital pieces of information for this study (estimated time for a repair) was determined by both data sources using a different variation of the Schedule of Rates.

5. The notion of time significance was used to identify the trades and the tasks within each of the trades to be examined as part of this study.

Chapter 7: Responsive Repairs Data Analysis and Discussion of Results

7.1 Introduction

Unlike construction labour, maintenance tradesmen often perform a wide range of tasks some routine, some regular but infrequent and sometimes they are confronted with tasks they have never come across before. Each day for repair and maintenance is a different day that could bring with it any combination of these tasks.

This chapter reports and discusses the results of examining basic task level productivity. The objective of the data analysis is to examine historical repair and maintenance data in order to:

1. Identify the variability that exists in productivity levels while performing different repair and maintenance tasks
2. Attempt to identify the factors that influence maintenance labour productivity

Understanding the variability in productivity levels and the factors that influence it will help to identify ways to improve maintenance labour productivity.

The chapter is structured as follows.

Section 7.2 describes the process of preparation and examination of the data in order to put it in a format that will enable the data to be analysed in accordance with the research methodology.

Section 7.3 discusses the analysis of the Construction Division Repair and Maintenance Section (CDRMS) data. This includes full analysis of the joinery tasks as an example, examining the impact of materials content on productivity by comparing the productivity of tasks with and without material content for all trades for both data sources as well as exploring the seasonal variability in productivity levels. This is followed by a summary and discussion of the results for all CDRMS trades.

Section 7.4 discusses the analysis of Hillcrest Maintenance Services (HMS) task performance data.

Section 7.5 examines the impact of individual tradesmen's performance from both data sources on productivity. The section also addresses the productivity of the various trades.

Section 7.6 explores the impact of size of repair task on productivity.

Section 7.7 examines the impact of the working day on productivity.

Section 7.8 explores the difference in productivity between HMS and CDRMS

Section 7.9 reports the major conclusions of the analysis.

7.2 Framework for Data Analysis

The data analysis methodology involved the determination of the significant trades and the tasks within these trades that contributed the most to the overall repair and maintenance operation. Following this using the Earned Hours Productivity Index as described in Section 3.10.3 it was possible to plot the variation in productivity for each of the variables set out in Section 7.1.

7.2.1 Choice of Trades

The study is primarily concerned with investigating the productivity of labour in maintenance and repair operations. A comparative study of the variability in productivity levels experienced by maintenance tradesmen is therefore necessary. The main requirement for choosing the trades was that the operational characteristics for the trades should be sufficiently different and therefore, there would be varying levels of labour input. This would indicate the differences in variability in productivity levels in different trades.

Repairs were therefore grouped according to trades and the total cost, number of jobs and the total time for each trade was calculated.

Table 7.1 and Table 7.2 provide a summary of the trades and their respective contributions to the repair and maintenance expenditure during the time periods considered

Table 6:1 Summary of CSI & TSI grouped by trade 2009/10

Trade	Total Billed	% Cost Contribution	No. of Jobs	Total Hours	% Time Contribution
Plumber	£1,220,050	34%	24,761	60,221	33%
Joiner	£1,012,115	28%	12,852	44,220	25%
Electrician	£521,311	14%	10,736	35,891	20%
Miscellaneous	£357,073	10%	2,023	7,971	4%
Roofer	£177,649	5%	1216	5,640	3%
Glazier	£136,777	4%	1,298	18,782	11%
Plasterer	£104,639	3%	1,018	3,339	2%
Builder	£50,995	1%	376	1,688	1%
Painter	£43,528	1%	449	1,419	1%

Table 7:2 Summary CSI & TSI grouped by trade 2010/11

Trade	Total Billed	% Cost Contribution	No. of Jobs	Total Hours	% Time Contribution
Plumber	£1,319,428	34%	25,202	50,871	34%
Joiner	£1,032,909	27%	11,644	41,416	28%
Miscellaneous	£434,491	11%	1,940	7,993	5%
Electrician	£396,940	10%	9,014	36,942	18%
Roofer	£312,183	8%	1,614	7,494	5%
Plasterer	£121,409	3%	1,039	9,974	7%
Builder	£104,051	3%	752	3,046	2%
Glazier	£68,966	2%	507	1,115	1%
Painter	£49,746	1%	562	1,467	1%

As can be seen from the tables above, it is clear that the Joinery, Plumbing and the Electrical trades were the main contributors to the maintenance and repairs operations during both time periods. It was decided to concentrate on the above trades for the following reasons:

a. They were all recognised as cost and time significant from the initial round of analysis.

b. There are enough records available for these trades to allow a robust statistical analysis.

c. There are varied tasks within each of the trades to enable comparison to be made between the productivity for the various tasks.

d. The trades represent the most common repairs frequently carried out by the department.

e. A sufficient number of tradesmen are listed for each of the trades to enable meaningful comparisons of performance.

Accordingly, this study concentrated on tasks performed by these trades in order to investigate labour productivity.

7.2.2 Choice of Repair Tasks

Following on from the identification of the trades, the data was sorted according to the work description in order to partition the data according to basic repair tasks for the trades to be examined. Given the varied tasks carried out by each of the trades selected above, it was expedient to limit the examination to those tasks performed by each trade that were significant in terms of cost and time. Similar to the choice of trades, the tasks needed to have different characteristics to ensure a variety of levels in terms of labour input. Table 7.3 contains a summary of the biggest contributors to the repair and maintenance expenditure.

Table 7:3 Summary of contributors to the repair and maintenance expenditure.

Task	2009/10 Data				2010/11 Data			
	Total Spend	Total Time	% Spend	% Time	Total Spend	Total Time	% Spend	% Time
Door Repairs	240,540.00	7411	24%	18%	252,693.00	7152	24	17
Gain Entry	81,632.00	2265	8%	5%	94,461.00	2450	9	6
Ironmongery/Fittings	130,475.00	4770	13%	11%	178,229.00	5698	17	14
No Heat/Hotwater	560,934.00	11035	46%	18%	572,855.00	11316	43	22
Clear Choke	109,777.00	2585	9%	4%	114,269.00	2642	9	5
Check Electrics	177,436.00	4661	34%	13%	185,265.00	4837	47	13
Lighting Repairs	199,791.00	6542	38%	18%	183,138.00	5601	46	15

It should be noted that the selection of the tasks was made on the basis of time significance and the availability of enough billing records to enable the analysis of the tasks. In the initial data obtained from CDRMS, the description of the jobs was listed in accordance to a Unit of Work key (UoW) as indicated in section 6.5.1. The UoW key groups certain repair tasks together, for example, a task such as No Heat/Hot Water would also include Radiator Repairs, and similarly, Check Electrics would include a number of tasks within it such as Fan Repairs. Other UoW key jobs would indicate specific tasks such as repairs to Ironmongery/Fittings or Clear Choke.

Following this, the billing information which is recorded in a separate system and includes specific repair information as indicated in section 6.5.2 is considered. This information includes description of the actual work carried out; from this the tasks of Radiator Repairs, Heater Repairs and Fan Repairs were selected due to the availability of enough records to facilitate the data analysis. Accordingly, this study focusses on the following tasks as the basis for further investigation:

1. Joinery Tasks – Door Repairs, Ironmongery/Fittings and Gain Entry.

2. Electrical Tasks – Lighting Repairs, Heater Repairs and Fan Repairs.
3. Plumbing Tasks – No Heat/Hot Water, Radiator Repairs and Clear Choke

7.2.3 Data Examination

The data is for five time periods covering jobs that were performed on or around the months of January, April, June, September and November 2013. The original data consisted of over 5200 repair jobs which were subjected to the data preparation exercise described above.

Table 7.4 indicates the trades and tasks within each trade that were considered for further analysis.

The data is for a single period covering jobs that were performed during or around the month of January 2013. The original data consisted of 1560 repair jobs which were subjected to the data preparation exercise described above.

Table 7:4 Selected Trades and Tasks from CDRMS data

Trade	Task	Total Value	Total Hours	Average PI EH
	Lighting Repairs	£ 19,792.00	521	1.25
	Heater Repairs	£ 5,670.00	97	1.20
	Fan Repairs	£ 4,760.00	83	1.57
ELECTRICAL		**£ 30,222.00**	**701**	**1.34**
	Ease/Repair Door	£ 14,246.00	449	1.64
	Ironmogrey/Fittings	£ 13,716.00	373	1.65
	Gain Entry	£ 8,189.00	281	0.92
JOINERY		**£ 36,151.00**	**1103**	**1.40**
	No Heat/Hot Water	£ 26,680.00	931	1.17
	Clear Choke	£ 8,047.00	246	1.34
	Radiator Repairs	£ 5,286.00	202	1.77
PLUMBING		**£ 40,013.00**	**1379**	**1.43**

7.3 Analysis of CDRMS Data

The way a repair task is planned and carried out could have an impact on labour productivity, either positive or negative. As well as how productive the performance of the task was, an assessment of tasks with and without material content as well as seasonal variability will be carried out. The aim of the analysis is to identify the variability in productivity levels during the performance of the same task and to explore the causes of such variability.

The analysis was carried out for the data collected from CDRMS, seasonal data; that is data from the different time periods and the combined set of data for all repairs.

7.3.1 Analysis of CDRMS Joinery Tasks

As discussed in chapter 5, the joinery tasks selected for examination were Door Repairs, Ironmongery/Fittings and Gain Entry. Door Repairs included all repairs to doors both internal and external including basic adjustments, securing doors, fixing door posts, checking seals etc. Ironmongery/Fittings included all repairs to door and window handles, fitting draught excluders, basic lock repairs etc. Gain Entry deals with tasks relating to arranging entry with tenants and, in the case of lost keys, arranging entry for police, utility engineers etc. A sample of CDRMS joinery repairs data is available in Appendix C1.

Data for the joinery tasks provided by CDRMS was considered as a single data set and according to the different time periods. The data analysis results for the CDRMS joinery tasks is summarised in Table 7.5. The table indicates the Mean and Standard Deviation for all the joinery tasks under examination, including tasks with and without material content.

Table 7:5 Summary of CDRMS Joinery Task Results

JOINERY TASKS	COMBINED		JANUARY		APRIL		JUNE		SEPTEMBER		NOVEMBER	
	AVG PIEH	STD	AVG PIEH	STD	AVG PIEH	STD	AVG PIEH	STD	AVG PIEH	STD	AVG PIEH	STD
Door Repairs	1.64	**1.20**	1.40	**0.81**	1.53	**1.20**	2.00	**1.60**	1.52	**0.89**	1.68	**1.18**
Door Repairs – with material content	1.14	**0.55**	1.10	**0.41**	1.19	**0.66**	1.30	**0.60**	1.07	**0.64**	1.11	**0.40**
Door Repairs – without material content	1.88	**1.34**	1.57	**0.92**	1.66	**1.31**	2.20	**1.70**	1.81	**0.91**	2.03	**1.35**
Gain Entry	0.92	**0.42**	1.00	**0.30**	0.53	**0.20**	1.00	**0.30**	1.10	**0.56**	1.05	**0.32**
Gain Entry – with material content	0.87	**0.33**	1.03	**0.31**	0.52	**0.17**	1.00	**0.30**	0.95	**0.27**	N/A	**N/A**
Gain Entry – without material content	0.89	**0.38**	0.98	**0.30**	0.55	**0.23**	1.00	**0.40**	1.26	**0.75**	N/A	**N/A**
Ironmongery/Fittings	1.67	**0.87**	1.57	**0.95**	1.35	**0.59**	1.70	**0.92**	1.83	**1.00**	1.52	**0.63**
Ironmongery/Fittings – with material content	1.61	**0.84**	1.18	**0.37**	1.57	**0.78**	1.66	**0.88**	1.80	**1.08**	1.51	**0.63**
Ironmongery/Fittings – without material content	1.76	**0.92**	1.65	**1.08**	1.88	**0.90**	1.80	**1.02**	1.87	**0.89**	1.54	**0.67**

7.3.2 Combined Joinery Task Analysis

Combined tasks are the individual repair types performed during the entire time period without consideration of season or material content. Table 7.6 indicates the productivity of the repair types considered.

Table 7:6 Combined joinery repair types productivity

Combined Joinery Repair Task	**Mean PI EH**	**STD**
Door Repairs	1.64	1.20
Ironmongery/Fittings	1.67	0.87
Gain Entry	0.92	0.42

Average productivity is denoted by a productivity index of (1.0). A PI value >1.0 is high productivity and <1.0 is low productivity. Considering the three joinery tasks examined, it could be argued that Ironmongery/Fittings with a mean PI value of 1.67 and a STD value of 0.87 is an indication of high productivity in task performance. Gain Entry, however, with much less dispersion of values around the mean, with a STD value of 0.42, has a lower mean PI value and therefore lower productivity. It could be argued, given the nature of the task that involves liaising with others such as the tenant, utilities providers, the police etc. may hinder the performance of the task and lead to lower productivity. The Door Repairs task with a mean PI value of 1.64 indicates high productivity of task performance; however, a standard deviation of 1.2 indicates that the 2/3 of the PI values lie between 0.44 and 2.84, a wide range of values. Figure 7.1 shows a sample of typical variability in productivity for a joinery task.

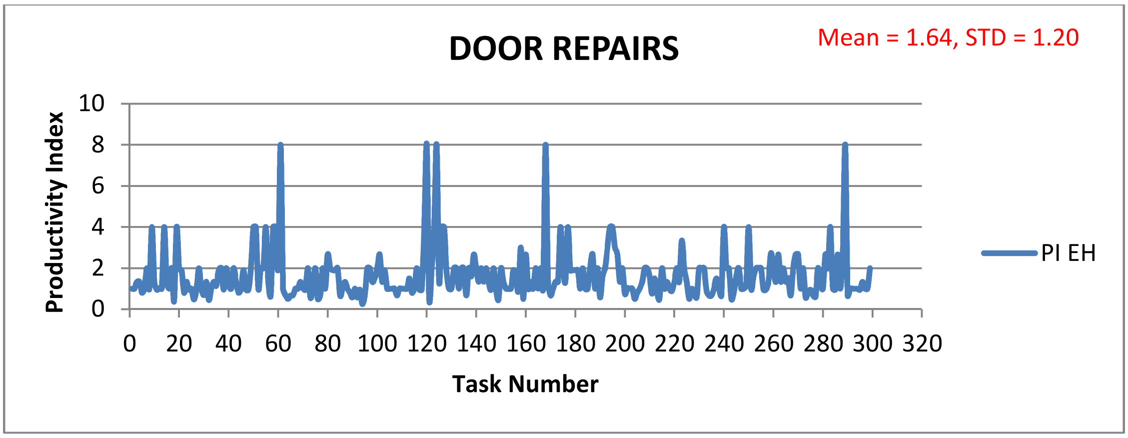

Figure 7:1 Door Repairs Variability

7.3.3 Analysis of CDRMS Joinery Tasks with and Without Material Content

Table 7.7 presents the results of analysing the joinery tasks with and without material content.

Table 7:7 Joinery tasks with and without material content

JOINERY TASKS	AVG PIEH	STD
Door Repairs – with material content	1.14	**0.55**
Door Repairs – without material content	1.88	**1.34**
Gain Entry – with material content	0.87	**0.33**
Gain Entry – without material content	0.89	**0.38**
Ironmongery/Fittings – with material content	1.61	**0.84**
Ironmongery/Fittings – without material content	1.76	**0.92**

The results indicate that repairs with no material content have higher productivity than repairs with material content. The presence of material content may indicate a more complex repair job that requires more time and resources to complete: alternatively, reduced productivity maybe a result of the lack of availability of the required material. On the other hand, however, the presence of material content may indicate a straightforward replacement job and therefore may be expected to be easier to perform. Of course there are times when a seemingly, easy repair or replacement may consume a long period of time due to a number of factors such as tightness of screws or bolts, amount of rust accumulated or the awkward position of the part requiring repair or replacement.

Using the Door Repairs task as an example, the tasks without material content had PI mean value of 1.88 indicating high level of productivity even though the STD value of 1.34 indicates a relatively wide dispersion of values around the mean. The tasks with material content have a mean PI value of 1.14 and STD value of 0.55. While this is still considered as high productivity with less dispersion of values, it is lower than the performance of the same task without material content. The data shows that most of the large variation was for repairs with material content and therefore, the longer time it takes to complete the repair with material content could be attributed to the delay caused by the tradesman having to go and purchase material required to complete the repair. It could also be attributed to an unforeseen complication that had occurred while performing the repair job.

7.3.4 CDRMS Seasonal Joinery Task Analysis

Seasonal variability in productivity levels was considered. Data was available for tasks carried out during different times of the year to coincide with the various seasons. Since the variable under examination is the 'season', all joinery tasks were put together in order to observe the seasonal variability for the whole trade. The results of the analysis are highlighted in Table 7.8. The results indicate that productivity of the joinery trade has fluctuated during the time periods under examination. In general productivity levels for the joinery trade has shown high PI values during the various time periods, the results indicate, however, that productivity had fluctuated by as much as 15% between the best and worst time periods which may not be considered as significant.

Table 7:8 Summary of Joinery tasks seasonal analysis

Month	All Tasks		Tasks with Material		Tasks without Material	
	Mean	STD	Mean	STD	Mean	STD
January	1.29	0.72	1.23	0.64	1.41	0.87
April	1.36	1.01	1.20	0.78	1.49	1.15
June	1.28	0.77	1.40	0.78	1.90	1.47
September	1.51	0.90	1.33	0.87	1.69	0.89
November	1.49	0.88	1.38	0.59	1.88	1.20

Analysis of the seasonal variability for tasks with and without material content indicate that productivity fluctuated by as much as 14% for tasks with material content and 26% for tasks without material content between the best and worst time periods. However, it is clear that tasks without material content remain more productive regardless of the time of the year repairs are carried out. Nor is there any obvious cause of or consistency in seasonal fluctuations.

7.3.5 Analysis of all CDRMS Trades Data

In the previous sections, the process of analysing the data was shown for the Joinery trade. The analysis was shown for the task combined performance, tasks with and without material content and seasonal variability. Table 7.9 summarises the results of the analysis for all trades and tasks for the CDRMS data.

A sample of CDRMS electrical and plumbing trades data is available in Appendices C2 and C3 respectively.

The electrical tasks selected for examination were Lighting Repairs which include repairs to communal lighting and repairs to light fittings, Fan Repairs which include repairing or renewing various types of extractor fans and Heater Repairs which include repairs to various types of electrical heating appliances. The results indicate that Fan Repairs with mean PI value of 1.57 and STD value of 0.95 had the highest productivity. Heater Repairs with mean PI value of 1.2 and STD value of 0.45 had the lowest. The results indicate however, that among all combined electrical tasks; values of standard deviation were low, indicating lower levels of dispersion of values around the mean.

The results for the electrical trade are consistent with the results for the joinery trade with respect to tasks with and without material content. Again it was found that for the electrical trade, the performance of those trades without material content is more productive than those involving use of material.

Table 7:9 Summary of results for all CDRMS trades and tasks

ALL TASKS	COMBINED		JANUARY		APRIL		JUNE		SEPTEMBER		NOVEMBER	
	AVG PIEH	**STD**	AVG PIEH	**STD**	AVG PIEH	**STD**	AVG PIEH	**STD**	AVG PIEH	**STD**	AVG PIEH	**STD**
JOINERY												
Door Repairs	1.64	**1.20**	1.40	**0.81**	1.53	**1.20**	2.00	**1.60**	1.52	**0.89**	1.68	**1.18**
Door Repairs – with material content	1.14	**0.55**	1.10	**0.41**	1.19	**0.66**	1.30	**0.60**	1.07	**0.64**	1.11	**0.40**
Door Repairs – without material content	1.88	**1.34**	1.57	**0.92**	1.66	**1.31**	2.20	**1.70**	1.81	**0.91**	2.03	**1.35**
Gain Entry	0.92	**0.42**	1.00	**0.30**	0.53	**0.20**	1.00	**0.30**	1.10	**0.56**	1.05	**0.32**
Gain Entry – with material content	0.87	**0.33**	1.03	**0.31**	0.52	**0.17**	1.00	**0.30**	0.95	**0.27**	N/A	**N/A**
Gain Entry – without material content	0.89	**0.38**	0.98	**0.30**	0.55	**0.23**	1.00	**0.40**	1.26	**0.75**	N/A	**N/A**
Ironmongery/Fittings	1.67	**0.87**	1.57	**0.95**	1.35	**0.59**	1.70	**0.92**	1.83	**1.00**	1.52	**0.63**
Ironmongery/Fittings – with material content	1.61	**0.84**	1.18	**0.37**	1.57	**0.78**	1.66	**0.88**	1.80	**1.08**	1.51	**0.63**
Ironmongery/Fittings – without material content	1.76	**0.92**	1.65	**1.08**	1.88	**0.90**	1.80	**1.02**	1.87	**0.89**	1.54	**0.67**
ELECTRICAL												
Lighting Repairs	1.25	**0.67**	1.21	**0.69**	1.16	**0.57**	1.34	**0.63**	1.38	**0.75**	1.21	**0.65**
Lighting Repairs – with material content	1.17	**0.49**	1.11	**0.51**	1.08	**0.38**	1.17	**0.33**	1.27	**0.54**	1.17	**0.50**
Lighting Repairs – without material content	1.48	**0.97**	1.40	**0.92**	1.56	**0.95**	1.48	**0.78**	1.80	**1.22**	1.33	**0.98**
Heater Repairs	1.2	**0.45**	1.20	**0.41**	1.42	**0.57**	1.46	**0.29**	N/A	**N/A**	1.08	**0.28**
Heater Repairs – with material content	1.1	**0.54**	1.03	**0.33**	N/A	**N/A**	N/A	**N/A**	N/A	**N/A**	N/A	**N/A**
Heater Repairs – without material content	1.3	**0.41**	1.32	**0.37**	N/A	**N/A**	N/A	**N/A**	N/A	**N/A**	N/A	**N/A**
Fan Repairs	1.57	**0.95**	1.42	**0.72**	1.38	**0.60**	1.80	**0.76**	1.70	**1.61**	1.70	**0.67**
Fan Repairs – with material content	1.37	**1.04**	1.75	**0.35**	N/A	**N/A**	N/A	**N/A**	N/A	**N/A**	N/A	**N/A**
Fan Repairs – without material content	1.76	**0.82**	1.91	**0.94**	N/A	**N/A**	N/A	**N/A**	N/A	**N/A**	N/A	**N/A**
PLUMBING												
No Heat/Hot Water	1.17	**0.58**	1.48	**0.64**	0.79	**0.38**	1.30	**0.52**	1.09	**0.41**	2.27	**1.14**
Radiator Repairs	1.77	**1.15**	2.10	**1.07**	2.41	**0.94**	1.36	**0.86**	2.07	**0.53**	1.15	**0.54**
Clear Choke	1.37	**0.58**	1.28	**0.45**	1.32	**0.60**	1.48	**0.53**	1.37	**0.73**	1.47	**0.54**

In terms of seasonal variability, it was found that the productivity of carrying out electrical tasks fluctuated by as much as 13% between the best and worst time periods. Analysis of the seasonal variability for electrical tasks with and without material content indicated that productivity fluctuated by as much as 15% for tasks with material content and 26% for tasks without material content between the best and worst time periods.

The seasonal variability observed in the performance of the electrical tasks, is not as large as that with observed the joinery tasks, but again, no consistent seasonal pattern is evident.

The plumbing tasks selected for examination were No Heat/Hot Water which included repairs to loss of pressure in boilers and other faults leading to loss of heating and/or hot water, Radiator repairs which include repairing or renewing wall mounted radiators and Clear Choke Repairs which include repairs relating to clearing blockages from sinks, hand wash basins, shower trays etc.

It should be noted that plumbing repairs selected for analysis had very little or no material content of any significance. The exception to this, where material content was present was for repairs involving renewing or replacing boilers or radiators. These repairs are considered as part of the Large Value Repairs analysis because of their value and the length of time to complete the repairs.

The combined performance of the plumbing tasks appears to be a consistent and productive performance. The No Heat/Hot Water task had the lowest PI average value (1.17 and STD of 0.58). Radiator Repairs with mean PI EH value of 1.77 and STD value of 1.15 had the highest productivity and high dispersion of values around the mean. Clear Choke Repairs had a mean PI EH value of 1.37 and STD value of 0.58.

Considering seasonal variability of the plumbing trade, the results indicated that productivity fluctuated during the time periods under examination. In general productivity levels with the exception of the month of April indicated high PI values. The analysis indicates, however, that productivity fluctuated by as much as 43% between the best and worst time. The plumbing tasks exhibited the largest seasonal variability in the performance among all the trades under analysis, but again, no consistent pattern was evident.

7.4 Analysis of HMS Data

Chapter 6 highlighted the differences between the sets of data obtained from CDRMS and HMS. Here joinery tasks performed by HMS will be considered. The data from HMS does not record material cost as the cost of material is added as a percentage to the total value of the repair job. Although it is possible to extract the cost of material from the total repair job, there is the potential to obtain inconsistent results. No distinction will be made between tasks with or without material. Data provided by HMS was as one data set and was not broken down according to different times of the year. This was due to the recent implementation of the new Computerised Maintenance Management System (CMMS). Considering the performance of the same tasks as carried out by HMS, the results are summarised in Table 7.10.

A sample of HMS joinery, electrical and plumbing trades' data is available in Appendices C4, C5 and C6 respectively.

Table 7:10 Summary of results for all HMS trades and tasks

Task	Mean PI	STD
JOINERY		
Ironmongery/Fittings	1.52	1
Door Repairs	1.07	0.87
Gain Entry	2.75	1.93
ELECTRICAL		
Lighting Repairs	1.41	1.07
Fan Repairs	2.15	2.22
Heater Repairs	1.24	0.85
PLUMBING		
No Heat/Hot Water	3.26	3.31
Radiator Repairs	N/A	N/A
Clear Choke Repairs	1.16	0.73

There was too small a number of Radiator Repairs carried out by HMS to merit their inclusion in the study. The results show that all tasks had generally high values of PI meaning high productivity of task performance. However, because of the high levels of dispersion, the very high average PI values may be misleading. The high PIs might be the result of higher tradesman performance. They may however be a result of the nature of the repair task or they could simply be errors in recording. Further examination of the likely reasons was therefore undertaken. It should be noted that the PI values were calculated using the SoR Standard Minute Value (SMV) used by HMS for estimating task duration.

Table 7.11 shows a comparison between the average estimated time and the average actual time to complete a repair for all tasks under examination. Since the Earned Hours Productivity Index is calculated as a function of estimated divided by actual repair times, it is crucial to have accurate estimation data in order to gain an accurate measure of productivity. The results however, show that for HMS estimated to actual repair times could vary by as much as 91% as can be seen in the case of the ‘Gain Entry’ task due to high estimated value.

Table 7:11 Comparison of HMS estimated and actual repair times

Task	Avg Est. Time (hrs)	Avg Actual Time (hrs)	Variance %
JOINERY			
Ironmongery/Fittings	1.15	1.19	-3.4
Door Repairs	0.85	1.3	-34.6
Gain Entry	2.22	1.16	91.4
ELECTRICAL			
Lighting Repairs	0.81	0.88	-8.0
Fan Repairs	1.53	1.17	30.8
Heater Repairs	0.91	1.06	-14.2
PLUMBING			
No Heat/Hot Water	1.52	1.02	49.0
Radiator Repairs	N/A	N/A	
Clear Choke Repairs	0.87	1	-13

The available data however, does not shed any light on the cause of the presence of such values. Figure 7.2 illustrates a typical variability in performance of a task performed by HMS.

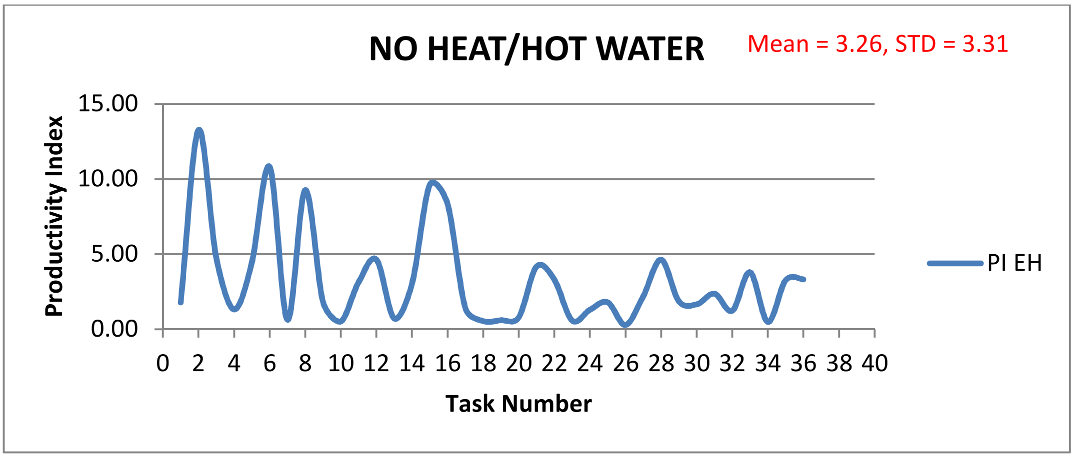

Figure 6:2 HMS No Heat/Hot Water Variability

7.5 Impact of Tradesmen Performance on Productivity

Using the PI EH productivity index, the average productivity for all tradesmen involved in the performance of repair tasks was analysed. The productivity index for each task was calculated for each tradesman or group of tradesmen performing the repair task. A list was compiled of all tradesmen and the associated mean PI for each tradesman was calculated. The result was plotted on a bar diagram from highest to lowest and the average was drawn. The tradesmen analysis was performed for each repair task and for the trades overall. This indicates the variability in tradesmen performance and provides an opportunity to examine the reasons for the variability.

The results of the tradesmen overall productivity are summarised in Table 7.12 for both data sources.

Table 7:12 Tradesmen Combined Productivity results

TRADE	CDRMS		HMS	
	Mean	STD	Mean	STD
Joinery	1.21	0.35	1.35	0.34
Electrical	1.16	0.39	1.57	0.4
Plumbing	1.21	0.38	1.76	1.07

7.5.1 CDRMS Tradesmen

Considering the joinery tradesmen, **CDRMS** had 44 tradesmen and/or gangs of tradesmen who were responsible for performing over 800 joinery repairs during the 5 month period being examined. Overall, the results indicate high levels of productivity as indicated by a mean PI value of 1.21 and a STD value of 0.35. Not all tradesmen however, performed well (Range = 0.56, 2.02) with 36% performing below the mean value. The results also show that the best performing tradesman was 280% more productive than the worst performing tradesman.

Table 7.13 indicates the performance of all CDRMS trades.

Table 7.13 CDRMS Trades Performance

Trade	Average PI	Range	Ratio best/worst	% performing below average
Joinery	1.21	0.56 - 2.02	260%	36%
Electrical	1.16	0.67 - 2.88	330%	58%
Plumbing	1.21	0.44 – 2017	390%	35%

Figure 7.3 shows the CDRMS joinery tradesmen analysis.

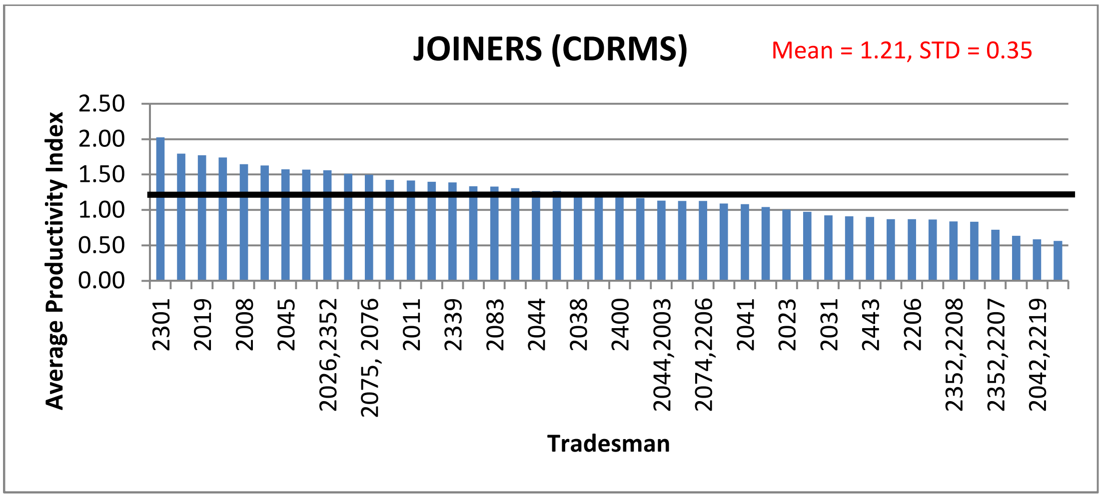

Figure 7:3 CDRMS Joinery Tradesmen

Figure 7.4 shows the CDRMS electrical tradesmen analysis.

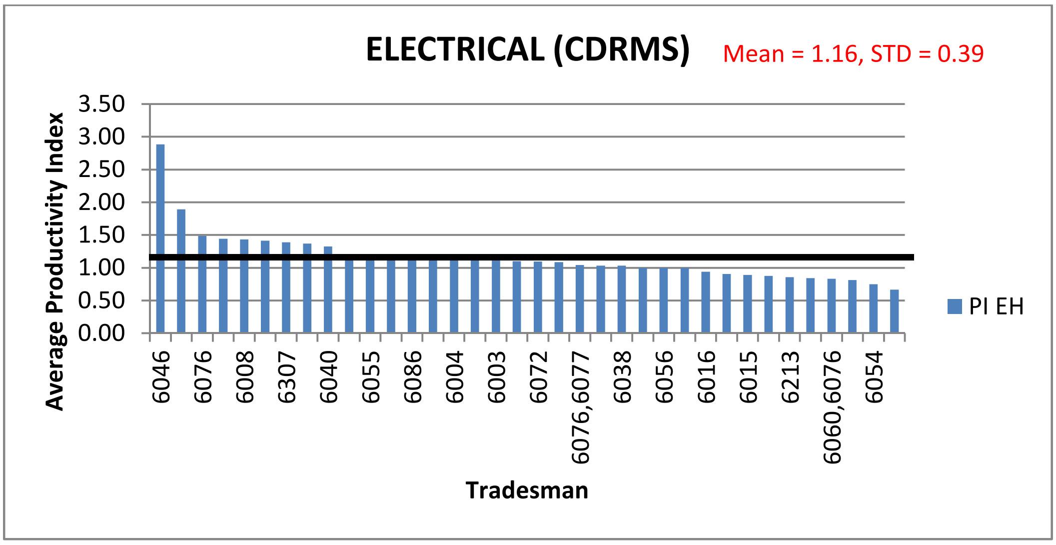

Figure 7:4 CDRMS Electrical Tradesmen

It should be noted that tradesman 6046 with the highest PI value may be considered as an outlier since he performed only 4 jobs. This can be compared for example with tradesman 6008 performing 78 jobs with a mean PI value of 1.43.

Figure 7.5 shows the CDRMS plumbing tradesmen analysis.

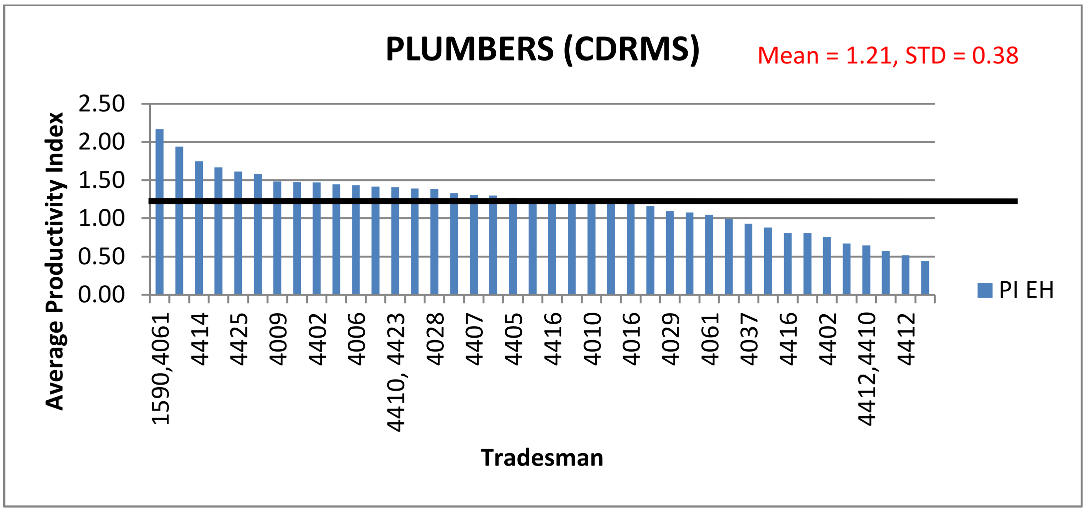

Figure 7:5 CDRMS Plumbing Tradesmen

7.5.2 HMS Tradesmen

The analysis of HMS tradesmen was carried out in the same way as CDRMS as detailed in the previous section. Table 7.14 indicates the performance of all HMS trades.

Table 7.14 HMS Trades Performance

Trade	Average PI	Range	Ratio best/worst	% performing below average
Joinery	1.35	0.85 – 1.96	130%	45%
Electrical	1.57	1.06 – 2.34	120%	57%
Plumbing	1.76	0.37 – 3.89	950%	50%

Figure 7.6 shows the HMS joinery tradesmen analysis.

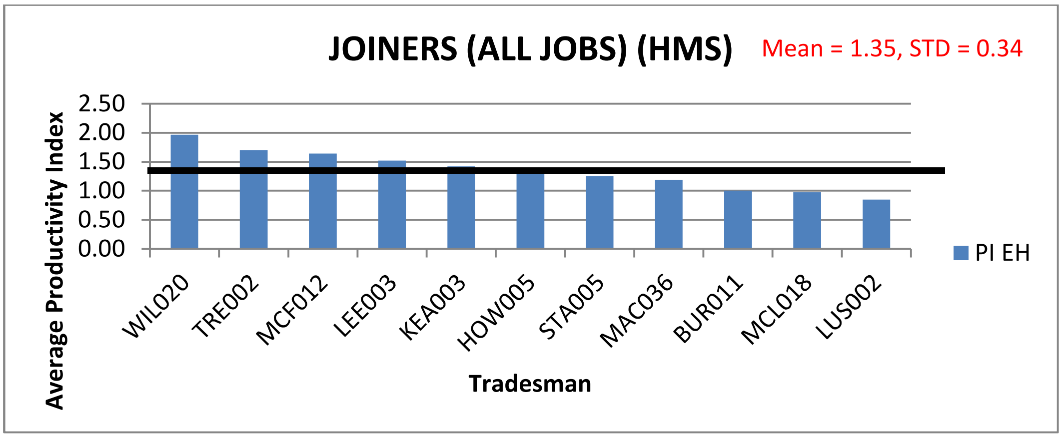

Figure 7:6 HMS Joinery Tradesmen

Figure 7.7 shows the HMS electrical tradesmen analysis.

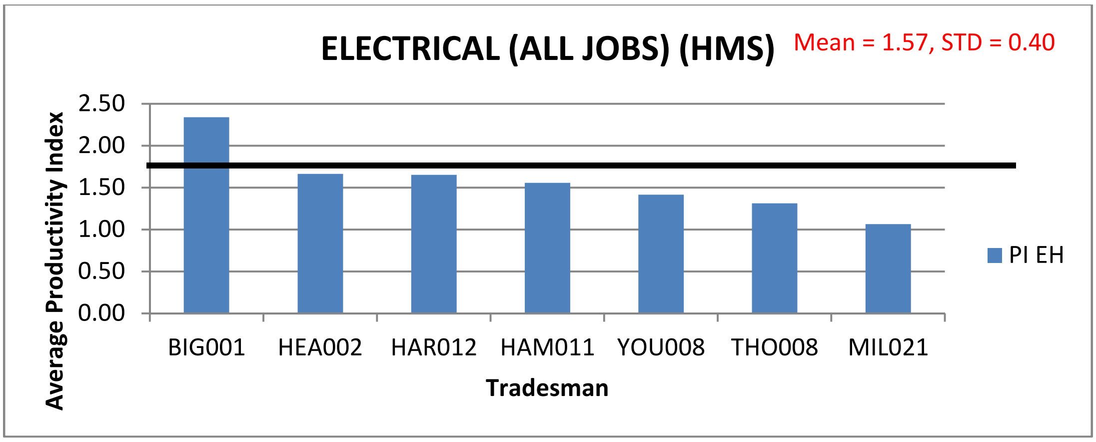

Figure 7:7 HMS Electrical Tradesmen

Figure 7.8 shows the HMS plumbing tradesmen analysis

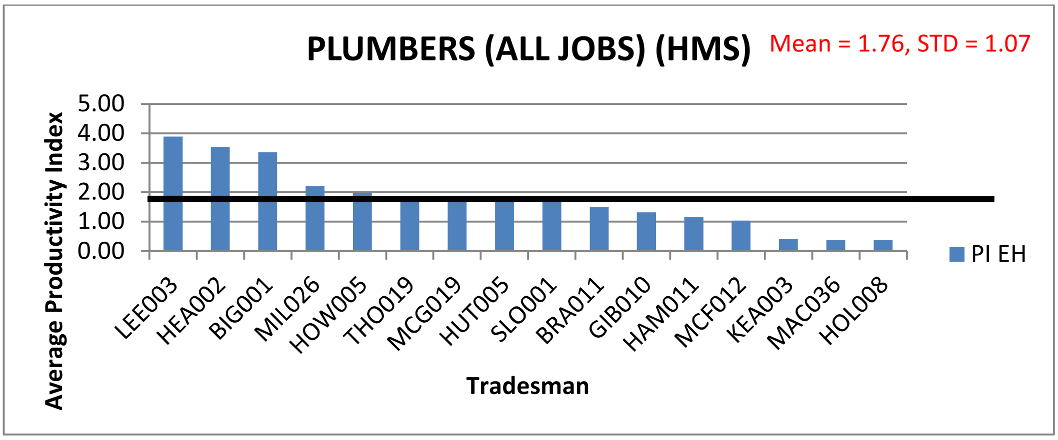

Figure 7:8 HMS Plumbing Tradesmen

It should be noted that the lowest 3 performing plumbing tradesmen have only performed 1 job each during the period.

7.5.3 Effect of repair task on tradesmen performance

Further analysis of tradesmen task performance indicates that tradesmen productivity fluctuates during the performance of different repair tasks. CDRMS joinery tradesmen for example performed better repairing doors and ironmongery/fittings than they did gaining entry repairs. Similarly, HMS plumbers performed better carrying out No Heat/Hot Water repairs than they did clearing blockages. One logical reason for this since the same tradesmen are involved could simply be an inaccuracy in the norms used to establish task duration. There could be however, many reasons for such fluctuation that cannot be determined from the data. The way in which we can determine the exact reasons for such differences is through accurate recording of delays and interruptions encountered during the performance of the repair task. This could be through the completion of tradesmen surveys, recording on mobile working terminals or through physical observation of tradesmen.

Individually tradesmen levels of productivity depend on the task being performed. A comparison of selected tradesmen from each trade who were involved in the performance of a significant number of repairs has indicated that tradesmen are more productive performing certain tasks than they are others. Figure 7.9 tracks the average productivity levels of three CDRMS joinery tradesmen during the performance of different tasks. The same was observed with the electrical and plumbing tradesmen.

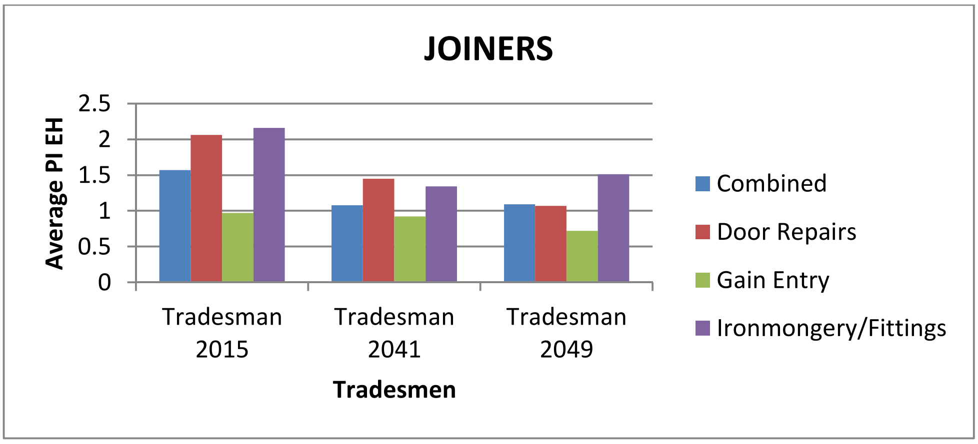

Figure 7:9 Sample CDRMS Joinery Tradesmen Task Performance Productivity

From this we can conclude that a) There is considerable consistency between all 3 tradesmen, and b) it suggests that the estimated times are consistently in error. Similar observations were made with HMS tradesmen.

7.6 Large Value Repairs

During examination of the data from both CDRMS and HMS it was noted that there were a considerable number of repairs across all tasks and trades that are of a larger value. Repairs that involve renewal, replacement or that are simply more complex and require significantly more time and/or resources to complete were selected using the cost significance theory described in Chapter 3. Unlike smaller/routine repairs, these repairs due to their value and the duration to complete a repair would benefit from any small improvement in productivity. In the case of CDRMS for example, it was observed that larger repairs in terms of value and duration have lower productivity when compared with the productivity of normal repairs as indicated in Table 7. 15. It was also discovered however, that for the CDRMS data, almost all large value repairs were under estimated in terms of task duration.

Table 7:15 Comparison of productivity of Large and normal Value Repairs

TRADE	CDRMS			HMS		
	Large Repair Mean	Normal Repair Mean	% change	Large Repair Mean	Normal Repair Mean	% change
Joinery	0.9	1.41	36%	1.36	1.78	23%
Electrical	0.84	1.34	37%	1.83	1.6	-14%
Plumbing	0.94	1.44	35%	1.98	2.21	10%

The results show the contrast in productivity levels among the trades from the different organisations. Compared with normal repairs, it was found that the joinery large value repairs were 36% less productive. The electrical repairs were 37% less productive and the plumbing repairs were 34% less productive.

For HMS, it was found that the joinery large value repairs were 23% less productive the routine repairs. The plumbing repairs were 10% less productive, but surprisingly, the electrical repairs were 14% more productive.

7.7 Productivity Week Day Analysis

Using the PI EH each of the repair tasks under examination including those tasks that were considered with and without material content, the average productivity for days of the week on which repairs were completed was considered. The aim of the analysis was to determine whether a consistent pattern exists to suggest that productivity is impacted by the working day.

For both data sources, using task completion date, the corresponding week day was identified as this was not readily available as part of the data set. The data source only records the completion date and not the day of the week when the work was carried out. A list was compiled for each task for the PI and week day. The data was then sorted according to days of the week and the average productivity index was calculated for each week day. Table 7.16 shows the combined productivity of CDRMS tradesmen according to the day of the week on which a repair task is carried out.

Table 7:16 Week day productivity of CDRMS trades

CDRMS	Mean PI EH						
Trade	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Joinery	1.39	1.25	1.31	1.36	1.31	1.23	1.48
Electrical	1.39	1.07	1.11	1.32	1.35	0.86	0.77
Plumbing	1.51	1.25	1.38	1.23	1.22	0.88	1.99
Average	**1.43**	**1.19**	**1.26**	**1.3**	**1.29**	**0.99**	**1.41**

Figure 7.10 shows a representation of the all trades average of the combined CDRMS Productivity Week Day Analysis.

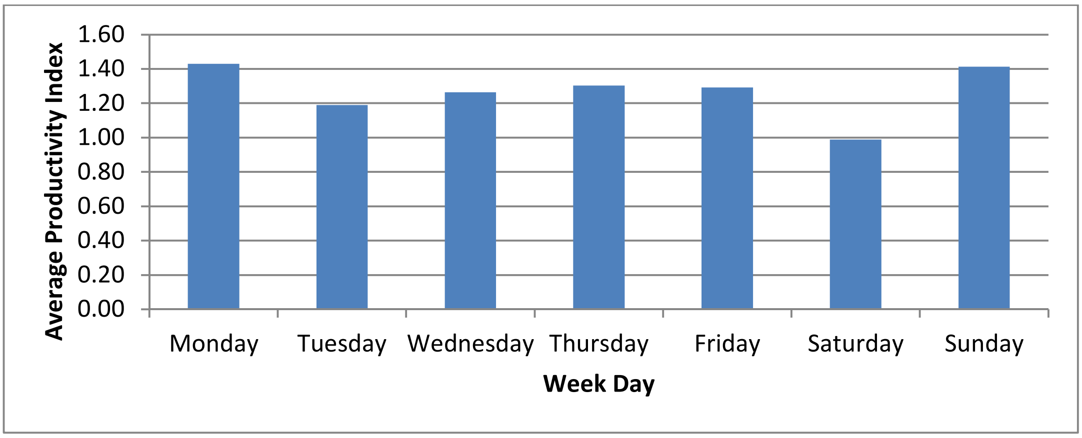

Figure 7:10 CDRMS All Trades Week Day Analysis

As can be seen productivity levels seem to be consistent throughout the week.

Productivity Week Day analysis for CDRMS was carried out for tasks with and without material content. This analysis was conducted for the joinery trade and only the lighting repairs task from the electrical trade, these being the only tasks involving the use of material in the repairs. Table 7.17 shows the productivity index for each day of the week for the selected tasks with and without material use.

Table 7:17 Week day productivity of CDRMS trades with and without material

Task	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Joinery - Material	1.13	1.09	1.16	1.28	1.07	0.65	0.65
Joinery - No Material	1.62	1.35	1.32	1.34	1.59	0.66	0.89
Electrical - Material	0.84	0.79	0.95	1.16	1.03	0.28	0.67
Electrical - No Material	1.11	1.76	1.34	1.79	1.34	0.98	1.28

The results indicate relatively close values of PI for all week days with Thursday indicating clearly higher productivity value. Values for Saturday and Sunday are lower with the likely explanation being the unavailability of material during the weekend days.

HMS tradesmen only work Monday to Friday with separate arrangement for covering emergency repairs during the weekends. Table 7.18 shows the combined productivity of HMS tradesmen according to the day of the week on which a repair task is carried out.

Table 7:18 Week day productivity of HMS trades

HMS	Mean PI EH				
Trade	**Monday**	**Tuesday**	**Wednesday**	**Thursday**	**Friday**
Joinery	1.38	1.46	1.36	1.3	1.53
Electrical	1.38	1.46	1.36	1.3	1.53
Plumbing	1.41	1.73	2.49	2.63	2.3
Average	**1.39**	**1.55**	**1.74**	**1.74**	**1.78**

Figure 7.11 shows a representation of the all trades average of HMS Productivity Week Day Analysis.

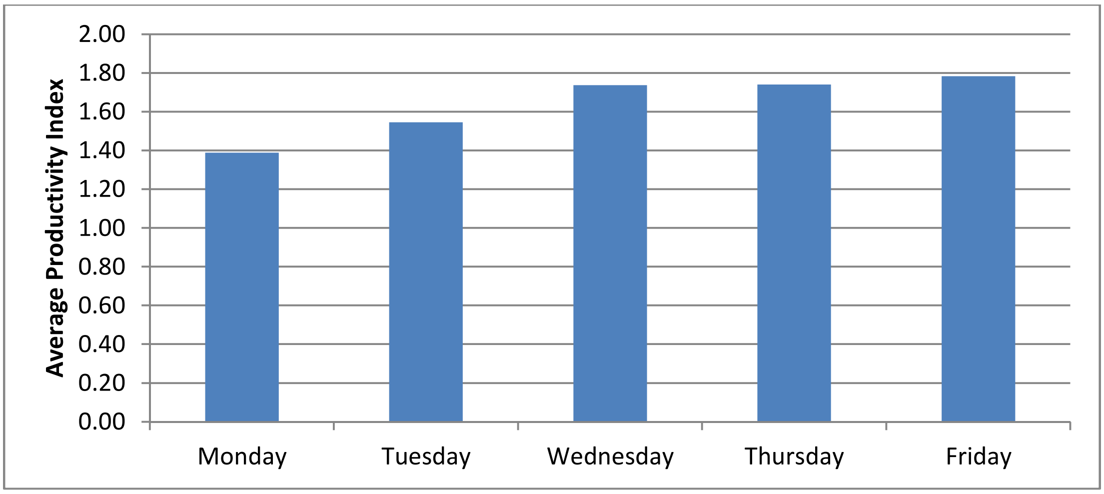

Figure 7:11 HMS All Trades Week Day Analysis

The results indicate that productivity levels are low at the beginning of the week and improve steadily until peaking on Fridays.

For the CDRMS data, the results confirm that productivity of tasks without material content is consistently higher for all trades in each week day. However, for both CDRMS and HMS, the results do not indicate any clear pattern to suggest that productivity is impacted by the day of the week in any consistent manner.

7.8 Productivity comparison between CDRMS and HMS

This section presents a comparison of the productivity of both data sources in order to contrast their respective approaches to the management and execution of repair and maintenance tasks. Table 7.19 shows the productivity of both organisations during the performance of the same tasks using each organisation's own estimation data. As can be seen, both organisations performed better in certain tasks than others; however, the overall average productivity indicates that HMS is 23% more productive than CDRMS. The results also indicate that there was a much higher dispersion of values in the case of HMS which means that the estimated times are consistently high.

Table 7:19 Productivity comparison between CDRMS and HMS

TASK	CDRMS		HMS	
	Mean PI	STD	Mean PI	STD
Door Repairs	1.64	1.20	1.07	0.87
Gain Entry	0.92	0.42	2.75	1.93
Ironmongery/Fittings	1.67	0.87	1.52	1.00
Lighting Repairs	1.25	0.67	1.41	1.07
Heater Repairs	1.20	0.45	2.15	2.22
Fan Repairs	1.57	0.95	1.24	0.85
No Heat/Hot Water	1.17	0.58	3.26	3.31
Radiator Repairs	1.77	1.15	N/A	N/A
Clear Choke	1.37	0.58	1.16	0.73
Average PI	**1.40**		**1.82**	

Previous discussion on tradesmen's impact on productivity as shown in Table 7.12 shows that HMS joinery tradesmen were 10%, electrical 26% and plumbing 31% more productive than CDRMS tradesmen performing the same tasks. Furthermore, referring to Table 7.15 where large value repairs were discussed, it was found that HMS joinery tradesmen were 34%, electrical 54% and plumbing 52% more productive than CDRMS tradesmen performing similar large repair tasks.

While these results strongly suggest that HMS runs a more productive operation, it should be noted that as explained in chapter 6, the HMS operations use the Schedule of Rates (SoR) system in order to estimate the value and duration of a repair task. CDRMS on the other hand use a combination of the SoR and a system based on their historical data. Careful consideration of the SoR system used by HMS indicates that it operates on the principle of a range of time which takes into account the variable nature of the repair work.

A basic task such as replacing a light pendent may take less or more time dependant on the age of the part to be removed, coats of paint applied around it and how tight the screws are. For example, if the task is estimated to take 50 minutes to complete, it may take 30 minutes or 70 minutes to complete. The SoR system applies 50 minutes however, for any job that falls within that range. The CDRMS system however, while using the same principle, takes into account historical task performance data in order to estimate the duration of a task. That is, norms may deviate from the SoR depending on the performance of previous similar tasks.

A further comparison that can be made involves the selection of a repair task from each trade from both data sources that has sufficiently large number of repairs. The selected tasks were, Ironmongery/Fittings (Joinery), Lighting Repairs (Electrical) and Clear Choke (Plumbing).

The comparison of the variability of productivity levels was made as follows:

- When the same task is carried out by each of the data sources under normal operating conditions, that is, using the PI values as calculated employing the estimation of task duration as determined by each organisation.
- Comparison of the productivity of both data sources with the productivity index calculated using the Standard Minute Value (SMV) as used by HMS.

The data used for the comparison is included in Appendix C7, C8 and C9. The results of the comparison are summarised in Table 7.20.

The comparison indicates that for all tasks performed by the various trades examined, when substituting the CDRMS task duration with the SMV used by HMS, productivity levels for all tasks and all trades as carried out by CDRMS were lower than the productivity calculated using their own estimation method by as much as a third. This confirms that HMS is more productive than CDRMS when the same estimated task duration is applied.

Table 7:20 Productivity comparison using SMV values

TASK	HMS	CDRMS		% Difference CDRMS (SMV) vs HMS
	Mean PI	Mean PI	Mean PI (SMV)	
Ironmongery/Fittings	1.52	1.51	1.14	33%
Lighting Repairs	1.40	1.25	1.08	30%
Clear Choke	1.16	1.31	0.93	25%

7.9 Summary and Conclusions

The 'Earned Hours' Productivity Index used throughout this study is based on the accurate estimation of task duration and any errors in this estimation could potentially have an impact on the derived productivity values. Examination of some of the repairs that indicated high PI EH values in the data, showed no reason for the higher variability. In the absence of any tangible reason for the variability in productivity levels during task performance, it could be argued that robust estimation of task duration and accurate recording of task performance data could have an impact on labour productivity.

Naturally, there was variability in productivity levels during the performance of the same task. Higher variability observed on occasions may be attributed to the nature of the repair task or the variations in performance from tradesman to tradesman rather than any external factor.

Repairs that do not involve the use of materials are found to be more productive in terms of earned hours than those tasks involving use of material. The longer time it takes to complete the repair with material content could be attributed to the delay caused by the tradesman having to go and purchase material required to complete the repair. It could also be attributed to the possibility that tasks involving materials were more complex that those that did not.

The amount of repairs and the associated productivity of certain tasks is influenced by seasonal variability but not in any systematic way.

Tradesmen are the most significant variable in this labour intensive operation. Any improvement in the productivity of labour, no matter how small will yield a reduction in costs for the organisation. Investment in labour selection and training, improved morale and general working conditions, can be justified in order to improve productivity.

The variables with the most impact on maintenance productivity identified from the results are the task, tradesman and material. The factors identified from the results that may influence labour productivity are the skill and motivation of the tradesman and the availability of the necessary materials.

Other factors that may have an effect on productivity are all related to the quality of initial information, these are:

- Inaccurate or insufficient information about the repair task
- Availability of tools and material
- Access to work site

The availability of tools and material and access to work site could be eliminated by receiving complete and accurate information about the repair task.

The accuracy and consistency of the norms has a significant impact on the absolute values of the productivity index, and on the robustness of the analysis.

Chapter 8: Opportunities for labour productivity improvements

8.1 Introduction

Similar to the construction industry, building maintenance organisations are hard pressed to find ways to gain a competitive advantage and improve their profitability. Accordingly, one of the few opportunities to improve competitiveness is to increase productivity.

Drewin (1982) suggested that productivity can be increased by improving levels of capital investments, by improving the skills of workers, or by the introduction of new technology and greater efficiencies in the use of existing technology. It is accepted that productivity improvements produce many benefits, productivity cannot however, be improved without incurring costs. Examples are costs for research and development, training, and the more direct costs of studying current productivity and designing and implementing better methods.

This chapter will address productivity improvement issues derived directly from the results of the data analysis. It is already established that maintenance labour productivity is impacted by a number of factors, these factors will need to be addressed and their effects mitigated in order to improve productivity.

8.2 Results derived improvements

Improving productivity in building maintenance will result in timely performance of maintenance tasks, reducing the cost of maintenance and increasing customer satisfaction. This research has focused on examining the productivity of labour in building maintenance operations. While the research has highlighted that little work has been carried out in this area, the data analysis has indicated that there are a number of opportunities for improving productivity. These will be discussed below.

8.2.1 Skill and motivation of tradesmen

The analysis results in section 7.5 indicated that a gap in productivity exists between the best and worst performing tradesmen. Across all tradesmen being considered, the gap was found to be on average 24% among CDRMS tradesmen and 61% among HMS tradesmen. This indicates that there is room for improvement between best and worst performers. These findings accord with the findings of Horner and Duff (2001) who state that to improve productivity care needs to be taken in the selection and training of the labour force, the work needs to be planned in detail, overtime working needs to be avoided, and the size of the labour force needs to be kept at minimum.

Selection of maintenance tradesmen who possess the skills and experience needed to carry out efficient and effective repair and maintenance is hugely important. Inexperience and lack of skills is a major problem and could seriously affect the time taken to complete maintenance and repair tasks, higher labour costs and poor quality of repairs.

The following steps could be considered in order to ensure that all tradesmen are performing to consistently high levels:

a. An assessment of the levels of skills and experience of those tradesmen identified as poor performers should be carried out in order to identify their training needs.
b. An investment is required to provide adequate training and continuous skills development to bring low performing tradesmen to the desired levels and ensure their continued development.

c. A mentoring scheme may provide a practical on-the-job training by pairing high and low performing tradesmen with a view to improving their skills and raising their productivity.

d. Establishing performance targets for tradesmen linked to pay and conditions of employment to act as motivation for higher productivity.

8.2.2 Delays and interruptions

Research of factors affecting labour productivity in the construction industry has indicated that delays and interruptions are among the causes of poor productivity (Noor, 1992; Talhouni, 1990; Thomas and Yiakoumis, 1987; Shaddad and Pilcher, 1984; Soekiman, 2011; Dai et al, 2009). This is also true for maintenance and repair operations. While the data from CDRMS does not provide an indication whether a maintenance task was completed on the first visit, data from HMS demonstrated that information as well as the reasons for non-completion.

The causes of delays captured by HMS are:

a. Lack of access
b. Need for additional tools and materials
c. Need for extra trades to complete the task
d. Inclement weather
e. Third party involvement

Capturing and understanding the types of delays and their causes is very important in order to address and mitigate their effect with the aim of improving productivity. Accordingly the recording of essential task performance information, in particular, delays and interruptions is necessary. A suggested improvement strategy here could be:

- To shadow tradesmen while carrying out maintenance and repair tasks to record the length and reasons of idle time, that is, time spent not working. It should be noted that the researcher has attempted to carry out such an exercise; however, lack of enthusiasm on the part of participating organisations for fear of non-acceptance by tradesmen rendered the attempt unsuccessful.

- To use mobile technology as is the case with HMS in order to capture essential information such as the duration and length of the delays.
- If technology is not being used, craftsmen questionnaire surveys may be used to record not only delays but other essential performance related information.

8.2.3 Material related productivity

The data analysis results as indicated in section 7.3.3 highlighted that repair tasks that do not involve the use of material are more productive than those involving material use. Time spent by tradesmen purchasing material or travelling back to the stores to obtain material could be considered as idle time, in the sense it is not time spent carrying out productive work. To improve productivity a strategy for material procurement should be developed that ensures for each trade that the minimum level of material is always available to tradesmen to enable them to carry out the maintenance tasks.

8.2.4 Quality of initial information

Examination of the early raw data collected from CDRMS has indicated that there are limitations in the collection of repair requests. The quality of initial information is important for proper planning of the repair and maintenance work. Sufficient information should be obtained to avoid any delays in planning the maintenance and repair work. The data indicated instances where a tradesman arrived to carry out repairs only to find the extent of the repair work to be much greater than planned or that they could not gain access to the work site. These delays can be avoided by implementing robust maintenance reporting procedures supported by a clear maintenance request form that includes:

- Property address
- Detailed description of fault or work required
- Clear access information

Staff manning the repairs call centre should be adequately trained to obtain accurate and detailed fault descriptions.

8.2.5 Maintenance management and control

A comparison of the productivities of the two organisations being examined showed that HMS is 23% more productive than CDRMS as shown in section 7.8. One difference in the operations of the two organisations is the extent to which technology is used. Management and control of maintenance operations is essential for improving productivity. Parida and Kumar (2009), state that organisations need information of maintenance performance for planning and controlling the maintenance process. As indicated in the literature review, in order to improve productivity it needs first to be measured (Horner and Duff, 2001; Parida and Kumar, 2009; Wireman, 2007). It has already been established however, that there is a lack of complete and accurate data relating to building maintenance productivity, performance of labour and its utilisation. Accordingly, identification and control of the factors influencing maintenance labour productivity would provide significant potential for improving productivity. For example, the system used by CDRMS does not provide any information on the type, frequency and duration of delays and interruptions encountered by tradesmen while carrying out repair and maintenance work. The CMMS used by HMS on the other hand offers the opportunity to record this information which is essential for any serious maintenance productivity improvement initiative.

To address this, the use of CMMS can potentially contribute to effective management and control of the maintenance process. Furthermore, a culture based on proper use of planning and scheduling software and mobile technology use has the potential to improve maintenance productivity. The data that comes from CMMS is what provides a productivity measure. Such a system would include automated time recording system to record total time worked as well as duration and causes of any delays. The system would also provide maintenance productivity reports on weekly/monthly/yearly basis containing productive time, delay time and cause, earned hours, maintenance cost information and other useful productivity data. The result will be a more transparent operation, with a powerful management tool, improved control of resources and the ability to identify opportunities for productivity improvement.

8.3 Summary and Conclusions

Improving the productivity of building maintenance is becoming a subject of interest for many organisations. The results of the data analysis described in chapter 7 have identified a number of critical areas to which ineffective and costly maintenance can be attributed. The absence or inefficient use of a Computerised Maintenance Management System (CMMS) is one of the most notable areas. Other areas where productivity improvement can be implemented are:

- Improve the levels of skill and motivation of tradesmen
- Reduce delays and interruptions
- Develop a material procurement strategy
- Improve the quality of initial maintenance information
- Implement a system for maintenance management and control

This is supported by the survey results which identified the factors influencing maintenance labour productivity to be:

- Level of skill and motivation of workmen
- Quality of information, vague/incomplete work instructions
- Labour turnover and absenteeism
- Availability of tools and material
- Access to the work site

In addition, the survey results clearly identified that there is significant potential to improve building maintenance labour productivity.

The chapter highlighted the opportunities derived from the data analysis for improving maintenance labour productivity. It is very clear that prior to implementing a productivity improvement plan, there is an urgent need for collecting complete and accurate productivity related data to enable the accurate analysis and assessment of productivity, clearly identify the factors that impact productivity and design a complete and efficient plan for continuous improvement.

Chapter 9: Conclusions and Recommendations for Future Research

9.1 Introduction

The construction industry in general and building maintenance in particular are very labour intensive and any improvement in labour productivity will reflect significantly on an organisation's overall performance.

The aims of the research project were to explore ways for improving maintenance labour productivity and reducing maintenance costs by 1) reducing the number of maintenance activities; and 2) improving the productivity of labour. The first aim of the research was met by investigating to what extent Integrated Logistic Support (ILS) could help to optimise maintenance strategy. This was achieved through the application of Failure Modes and Effects Analysis (FMEA) and Reliability Centred Maintenance (RCM) to a single building system, namely Rainwater Goods. ILS has been applied in many industries to optimise maintenance strategies and to support activities leading to high equipment availability and maintainability.

The second aim of the research was met by identifying the factors influencing maintenance labour productivity and examining the variability in productivity levels while carrying out basic repair and maintenance tasks. The factors influencing labour maintenance productivity were identified from the literature and a survey questionnaire was designed and circulated in order to rank these factors in order of importance. The second aim also involved collection, preparation and analysis of historical repair and maintenance data from two repair and maintenance organisations in order to examine the variability in productivity levels. Focusing on labour productivity made the measurement process easier and more controllable and has led to obtaining more reliable and accurate data.

9.2 Conclusions

1. The RCM decision logic process was critically reviewed. Some recommendations were made to clarify the logic process for selecting maintenance tasks. In the case of hidden failures, a failure finding task should be selected regardless of the failure consequences as it is necessary to identify the failure before action can be taken to prevent or lessen its effect. The logic process has indicated that if no suitable maintenance task can be identified; re-design is compulsory for health, safety and environmental consequences and desirable for operational and economic consequences. It is suggested to add to this stage of the analysis that Cost Benefit Analysis is recommended for operational, economic and appearance consequences to determine the viability of any recommended action.

2. The application of FMEA and RCM has the potential to lead to changes to maintenance strategies for RWG systems. Reactive maintenance was identified as the most applicable strategy for the majority of failure modes identified (60%). However, the application of RCM also indicated that 40% of the failure modes required condition based maintenance (CBM) which is not currently applied. Application of CBM strategy will undoubtedly result in a reduction in maintenance costs as the condition of a building element or system will be regularly monitored and maintenance tasks carried out only when necessary.

3. The application of FMEA and RCM are based on expert judgement for their effective implementation and require an investment in terms of time and resources. The application of RCM did not identify any health, safety, environmental or economic consequences. It is concluded therefore, that the application of a complicated system such as RCM or the investment required for such application within building maintenance in its entirety may not be

justifiable. This is with the exception of mechanical and electrical installations where similarities may exist to other industries in terms of understanding of failures and their consequences.

4. It has been established that productivity measures how much we produce per unit input. The literature identified a number of ways for measuring labour productivity depending on the reason for measurement and the availability of useful data. Measures of productivity include output per hour worked, earned value and earned hours. It was found that measurement of building maintenance labour productivity has not been the focus of any previous studies. Indeed no measures of productivity for building maintenance were specified. Accordingly productivity measures developed for the construction industry were found to be applicable to building maintenance. While each of the measures has its advantages and disadvantages, the preferred measure of labour productivity in building maintenance operations was found to be the Earned Hours productivity index expressed as estimated hours divided by actual hours.

5. While a great deal of research has been conducted to identify the factors affecting the productivity of labour in the construction industry, a review of the literature has found that no such attempt has been made to identify factors affecting labour productivity in repair and maintenance operations. Of the factors found in the literature that influence construction labour productivity it was established that almost all the factors identified as part of the mapping exercise were also relevant to maintenance and repair operation. Accordingly, the research project has identified 14 factors that influence the productivity of labour in repair and maintenance. These factors were the subject of a questionnaire survey conducted among a sample of Local Authorities, Housing Associations and Building Contractors in the UK. By using the relative

importance index technique, it was possible to identify the following factors as those that have the greatest impact on maintenance labour productivity:

- The level of skills and motivation of workmen;
- Quality of information and work instructions;
- Labour turnover and absenteeism;
- Availability of tools and material, and
- Access to the job site

6. Some of the causes of lower productivity found during the data analysis could be attributed to inaccurate or insufficient information about the repair task; the skill and motivation of the tradesman, availability of tools and material and access to work site. All these factors were confirmed by the results of the survey questionnaire.

7. Variability in productivity levels is found to exist while examining the performance of similar tasks. The analysis also found that during the performance of the same tasks, one of the data sources was almost 25% more productive than the other. This difference may be attributed either to the method for estimating task duration and/or the extent of use of technology.

8. When the same norms were used to calculate the productivity index for both sets of data, one organisation was found to be 30% more efficient on average than the other.

9. Repairs that do not involve the use of materials were found to be 20% more productive in terms of earned hours than those involving use of material. The use of material and especially when material is not available at the time of task performance leads to delays and interruptions that affect task performance and impact on levels of productivity.

10. Tradesmen were identified as the most significant variable in this labour intensive operation. Any improvement in the productivity of labour, no matter how small will yield a reduction in costs for the organisation. Investment in labour selection and training, improved morale and general working conditions, can be justified in order to improve productivity.

11. It is very clear that prior to implementing a productivity improvement plan, there is an urgent need to collect complete and accurate productivity related data to enable the accurate analysis and assessment of productivity. This project concludes that improvement in labour productivity is achievable by focusing on mitigating the effects of the factors identified as influencing productivity, in particular the five highest ranked factors by participants in the questionnaire survey. Future research on the effect of each individual factor on labour productivity will provide an opportunity for predicting future maintenance costs.

12. Improving the productivity of building maintenance is becoming a subject of interest for many organisations. The results of the data analysis described in chapter 7 have identified a number of critical areas to which ineffective and costly maintenance can be attributed. The absence or inefficient use of a Computerised Maintenance Management System (CMMS) is one of the most notable areas. Other areas where productivity improvement can be implemented are:

    - Improve the levels of skill and motivation of tradesmen
    - Reduce delays and interruptions
    - Develop a material procurement strategy
    - Improve the quality of initial maintenance information

- Implement a system for maintenance management and control

9.3 Recommendations for future research

Further research should continue on the topics that are covered in this research project in order to further develop understanding of maintenance labour productivity and how it may be improved. Some of the areas in which research should be carried out are discussed below.

9.3.1 Better understanding of factors influencing labour productivity:

The research project analysed the productivity of labour carrying out maintenance and repair tasks. To validate the present findings, quantifying the impact of the factors influencing maintenance labour productivity through an in-depth empirical analysis will provide better understanding of those factors and provide management with the opportunity to improve allocation of resources, increase tradesmen's motivation and enhance their commitment to productivity improvement.

9.3.2 Development of a regression model for predicting maintenance labour productivity:

This research project has identified a number of factors/variables that impact labour productivity; these are the repair task, the tradesman and material usage. A regression model to predict/estimate a value for productivity from the known values of these independent variables would allow assessments to be made of the effect on productivity of changes in the variables. This would provide maintenance managers/supervisors the opportunity to know with an acceptable certainty the future value of productivity given a known value of input variables. The possibility of developing a linear regression equation should be explored. It would take the following form:

$$P = a+b1x1+b2x2+b3x3+\cdots bnxn$$

where:

P = Productivity (dependent variable); x1, x2, x3,… represent the independent variables; a = a constant representing the intercept coefficient and b = a constant representing the relevant strength of each variable.

9.3.3 Productivity Improvement using Statistical Process Control

The data analysis results clearly indicate the variability in the performance of similar tasks when carrying out responsive maintenance work. Viewing building repair and maintenance tasks as a process; identifying the causes and magnitude of the variability presents an opportunity to understand and address these causes and improve the maintenance provision. Research should explore the possibility of employing techniques such as Statistical Process Control and in particular Control Charts for process analysis and improvement.

9.3.4 Maintenance management and control

The impact on productivity of developing a culture based on proper use of planning and scheduling software and mobile technology should be explored.

9.3.5 High variation in productivity levels

During the analysis of task performance data across all trades and all tasks under consideration, high variations in productivity levels were observed. It would be interesting to calculate how much of the variability is caused by the factors identified in the course of this research. Understanding of this kind of variability either good or bad is essential for effecting productivity improvement through eliminating the causes of poor productivity and analysing and disseminating the causes for high productivity.

9.3.6 Development of a productivity data acquisition system

There is a need for a standard productivity data acquisition system. The data acquisition system encompasses a collection of data, policies, procedures and techniques to capture productivity data from actual repair and maintenance operations. Furthermore, conducting a study aimed at standardisation of basic repair tasks through establishing standard repair times based on actual repair data, applicable for local setting and taking into account the skill and motivation of the tradesmen could be invaluable.

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APPENDICES

APPENDIX A1 - Failure Modes and Effects Analysis (uPVC)

Rainwater Goods System (uPVC) -
To collect, convey and discharge rainwater safely and efficiently away from the building.

Id. No.	Item/Element Identification	Item/Element Function		Failure Modes		Failure Mode Causes	Failure Effects			Remarks
							LE	NHE	EE	
1.1	**Guttering**	To collect and convey rainwater from roof surface to downpipe	A	Leaking water	1	Sagging or twisted gutter sections	√	√	√	
					2	Unsealed joints in gutter and between gutter outlet and downpipe	√	√	√	
					3	Deterioration (ageing)	√	√		
					4	Faults of joints material	√			
					5	Crazing or cracking	√	√		
			B	Overflowing water	1	Blockage or vegitation growth	√	√	√	
					2	Misalignment of gutter sections	√	√		
					3	The provision of downpipes is not sufficient	√	√		
					4	Heavy rain downpours	√	√		
			C	Fracture and cracking	1	Water freezing to ice	√	√		
					2	Sagging or twisted gutter sections	√	√	√	
					3	Deterioration (ageing)	√	√		
					4	Physical impact	√			

1.2	**Gutter Angle**	Join two sections of guttering to continue around a corner	A	No proper connection of gutter sections	1	Inadequate sealing	√			
					2	Misalignment of gutter sections	√			
					3	Faults of joint material	√			
		Allow rain water to continue flowing	B	Leaking water	1	Unsealed joints in gutter and between gutter outlet and downpipe	√	√	√	
					2	Deterioration (ageing)	√	√		
					3	Faults of joints material	√			
					4	Physical damage	√	√		
1.3	**Stop End Outlet**	To close a run of guttering and allows water to discharge by connecting to the downpipe.	A	Missing stop end	1	Heavy rain	√	√		
					2	Deterioration (ageing)	√	√		
					3	Physical damage	√	√		
			B	Not properly connected to the downpipe	1	Unsealed joints between gutter outlet and downpipe	√	√	√	
1.4	**External Stop End**	Closes off a run of guttering.	A	Loose stop end	1	Inadequate sealing, not watertight.	√	√	√	
			B	Missing stop end	1	Heavy rain	√	√		
					2	Deterioration (ageing)	√	√		
					3	Physical damage	√	√		

1.5	**Running Outlet**	Collect and convey rainwater along guttering	A	Overflowing water	1	Blockage or vegitation growth	√	√	√	
			B	Leaking water	1	Physical damage	√	√		
					2	Inadequate sealing	√	√	√	
					3	Deterioration (ageing)	√	√		
		Connect two gutter sections	C	No proper connection of gutter sections	1	Inadequate sealing	√	√	√	
					2	Misalignment of gutter sections	√			
					3	Faults of joint material	√			
		Allow rainwater to discharge through downpipe	D	Not properly connected to the downpipe	1	Unsealed joints between gutter outlet and downpipe	√	√	√	
			E	Blocked outlet	1	Blockage or vegitation growth	√	√	√	
1.6	**Gutter Support Bracket**	Fixes the guttering to the facia.	A	Loss of fixing	1	Inadequately nailed to fascia and wall	√			
					2	Lack of regular maintenance	√			
			B	Physical Damage	1	Vandalism	√			
					2	Physical impact	√			
			C	Defective support brackets	1	Wrongly designed	√	√		
					2	Poor workmanship	√			
					3	Lack of regular maintenance	√			

2.1	**Downpipes**	To convey and discharge rainwater into a drain or a gully	A	Leaking water	1	Blocked downpipe	√	√	√	
					2	Displaced downpipe	√	√	√	
					3	Joints are no longer effective	√	√	√	
					4	Lack of maintenance	√			
			B	Fracture and cracking	1	Water freezing to ice	√	√		
					2	Deterioration (ageing)	√	√		
					3	Physical impact	√			
2.2	**Hopper**	Collect rainwater and divert to a downpipe	A	Overflowing water	1	Blockage or vegitation growth	√	√	√	
		Connect gutter to downpipe	A	Leaking water	1	Inadequate sealing	√	√	√	
					2	Deterioration (ageing)	√	√		
2.3	**Shoe**	To discharge rainwater horizontally, clear of the wall, into a drain or hard standing.	A	Insufficient discharge	1	Blockage or vegitation growth	√	√		
					2	Heavy rain	√	√		
			B	Fracture and cracking	1	Deterioration (ageing)	√	√		
		Connect to downpipe	A	Loose shoe	1	Inadequate sealing	√	√	√	
					2	Vandalism	√			

2.4	**Downpipe Connector**	Connect two sections of downpipe in series	A	Loose connection	1	Crazing or cracking	√	√		
					2	Joints no longer effective	√	√	√	
2.5	**Branch**	To join two downpipes together.	A	Leaking water	1	Cracking or crazing	√	√		
					2	Joints no longer effective	√	√	√	
2.6	**Offset Bends**	To bring downpipe close to the wall.	A	Leaking water	1	Cracking or crazing	√	√		
					2	Joints no longer effective	√	√	√	
2.7	**Downpipe Bracket**	Fixes a downpipe to the wall	A	Loss of fixing	1	Inadequately nailed to fascia and wall	√			
					2	Lack of regular maintenance	√			
			B	Physical Damage	1	Vandalism	√			
					2	Impact	√			
			C	Defective support brackets	1	Wrongly designed	√			
					2	Poor workmanship	√			
					3	Lack of maintenance	√			

APPENDIX A2 - RCM Decision Diagram (uPVC)

Element Name: **Rainwater Goods System (uPVC)**

Id. No.	Item Identification		Failure Modes	Hidden failure	Failure Consequence						Maintenance Task					Inspection Method			Maintenance Task
		Id. No.			HC	SC	EC	OC	AC	NC	FBM	TBM	IBM	NM	RD	VI	NDT	DT	
1.1	**Guttering**	A	Leaking water						√		√					√			Check seals and cracked parts, maintain or replace as necessary.
		B	Overflowing water						√		√					√			Regular cleaning and flushing of gutters.
		C	Fracture and cracking							√			√			√			Carry out regular inspections.
1.2	Gutter Angle	A	No proper connection							√			√			√			Carry out regular inspections.
		B	Leaking water						√		√					√			Check seals, maintain or replace affected parts.
1.3	Stop End Outlet	A	Missing stop end						√		√					√			Replace as necessary.
		B	No proper connection to the downpipe							√			√			√			Carry out regular inspections.
1.4	External Stop End	A	Loose stop end							√			√			√			Carry out regular inspections.
		B	Missing stop end						√		√					√			Replace as necessary.
1.5	Running Outlet	A	Overflowing water						√		√					√			Regular cleaning and flushing of gutters.
		B	Leaking water						√		√					√			Check seals, maintain or replace affected parts.
		C	No proper connection							√			√			√			Carry out regular inspections.
		D	No proper connection to					√			√					√			Seal joints or replace affected parts.

			the downpipe																
		E	Blocked outlet	□□	□□	□□	□□	√		□□	√	□□	□□	□□	□□	√	□□	□□	Regular cleaning and flushing of gutters.
				□□	□□	□□	□□		□□	□□		□□	□□	□□	□□	□□	□□	□□	
1.6	Gutter Support Bracket	A	Loss of fixing	□□	□□	□□	□□		√	□□	√	□□	□□	□□	□□	√	□□	□□	Maintain, re-affix bracket, replace nails as necessary.
		B	Physical damage	□□	□□	□□	□□		√	□□	√	□□	□□	□□	□□	√	□□	□□	Inspect and maintain as required.
		C	Defective support brackets	□□	□□	□□	□□			√		□□	√	□□	□□	√	□□	□□	Carry out regular inspections.
				□□	□□	□□	□□			□□	□□	□□	□□	□□	□□	□□	□□	□□	
2.1	**Downpipes**	A	Leaking water	□□	□□	□□	□□		√	□□	√	□□			□□	√	□□	□□	Maintain, replace, reposition downpipe. Clean and flush as necessary.
		B	Fracture and cracking		□□	□□			□□	√	□□	□□	√		□□	√		□□	Carry out regular inspections.
				□□	□□	□□	□□	□□	□□	□□	□□	□□	□□	□□	□□	□□	□□	□□	
2.2	Hopper	A	Overflowing water	□□	□□	□□	□□		√	□□	√	□□	□□	□□	□□	√	□□	□□	Clear/flush as necessary.
		B	Leaking water	□□	□□	□□	□□		√	□□	√	□□	□□	□□	□□	√	□□	□□	Check seals, maintain or replace affected parts.
				□□	□□	□□	□□	□□	□□	□□	□□	□□	□□	□□	□□	□□	□□	□□	
2.3	Shoe	A	Insufficient discharge	□□	□□	□□	□□		□□	√		□□	√	□□	□□	√	□□	□□	Carry out regular inspections.
		B	Fracture and cracking	□□	□□	□□			□□	√		□□	√	□□	□□	√		□□	Carry out regular inspections.
		C	Loose shoe	□□	□□	□□	□□		√	□□	√	□□	□□	□□	□□	√	□□	□□	Seal joints or replace affected parts.
				□□	□□	□□	□□	□□	□□	□□	□□	□□	□□	□□	□□	□□	□□	□□	
2.4	Downpipe Connector	A	Loose connection		□□	□□				√		□□	√		□□	√		□□	Carry out regular inspections.
2.5	Branch	A	Leaking water						√	□□	√	□□			□□	√	□□	□□	Seal joints or replace affected parts.
2.6	Offset Bends	A	Leaking water						√	□□	√	□□			□□	√	□□	□□	Seal joints or replace affected parts.

2.7	Downpipe Bracket	A	Loss of fixing	□□	□□	□□	□□		√	□□	√	□□	□□	□□	□□	√	□□	□□	Maintain, re-affix bracket, replace nails as necessary.
		B	Physical Damage	□□	□□	□□	□□			√		□□	√	□□	□□	√	□□	□□	Carry out regular inspections.
		C	Defective support brackets	□□	□□	□□	□□			√		□□	√	□□	□□	√	□□	□□	Carry out regular inspections.
				□□	□□	□□	□□	□□	□□	□□	□□	□□	□□	□□	□□	□□	□□	□□	

APPENDIX B1 – Copy of Survey into Maintenance Productivity

Survey Questions

Section 1 – General Information

1.1 Respondent's Name

1.2 Department

1.3 Type of Department:

Local Authority ☐ Housing Association ☐ Contractor ☐

1.4 Number of maintenance personnel employed:

☐ ≤20 ☐ 21 – 50 ☐ 51 – 100 ☐ 101 – 200 ☐ ≥200

1.5 What is the department's average annual spending on or income generated from maintenance activities?

☐ ≤1 Million ☐ 1 Million – 5 Million ☐ 5 Million - 10 Million ☐ ≥ 10 Million

1.6 Does the department sub-contract any part of the maintenance work?

☐ Yes No ☐

1.7 If the answer to the above question is yes, please indicate % of work sub-contracted.

☐ 1 - 20% ☐ 21 – 40% ☐ 41 – 60% ☐ 61 – 80% ☐ 81 - 100%

Section 2 – Effectiveness of Maintenance Department

2.1 Does the department measure labour productivity in relation to maintenance activities?

Yes ☐ No ☐

2.2 If the answer to the above question is yes, what methods are used by your department to measure labour productivity, tick all that apply:

No.	Measurement method	Tick
1	Total number of Jobs completed by the department in a given time period (day, week, month etc.)	
2	Comparison of actual and estimated time to complete a repair.	
3	Output per man hour	
4	Other, please specify	

2.3 How important is labour productivity on your list of managerial priorities? Please tick one box.

☐ Very Important ☐ Important ☐ Somewhat Important ☐ Not Important ☐ Unsure

3.4 Do maintenance trades people understand their role in helping the department achieve its objectives?

☐ All Do ☐ Some Do ☐ A few Do ☐ None Do ☐ Don't Know

3.5 Does the department regularly analyse work processes and work flows?

☐ Always ☐ Sometimes ☐ Hardly Ever ☐ Not at all ☐ Don't Know

3.6 Does the department run productivity improvement initiatives?

☐ Yes ☐ No

If the answer is yes, please specify ………………………………………….

Section 3 – Maintenance Productivity

3.1 From the list of factors that may influence maintenance labour productivity please indicate by ticking the appropriate column, the relative importance of each of the factors to both responsive/reactive maintenance and planned maintenance.

Responsive/Reactive Maintenance

No.	Factors affecting maintenance labour productivity	Very important	Important	Somewhat important	Not important

Planned/Programmed Maintenance

No.	Factors affecting maintenance labour productivity	Very important	Important	Somewhat important	Not important

3.2 Does the department use a maintenance management system?

☐ Yes ☐ No

If the answer is yes, which one ………………

3.3 Does the department operate maintenance and repair control system in order to identify maintenance and repairs problems?

☐ Always ☐ Sometimes ☐ Hardly Ever ☐ Not at all ☐ Don't Know

3.4 If the answer to the above question is anything other than 'Not at all', how effective do you consider the system to be?

☐ Very Effective ☐ Effective ☐ Somewhat Effective ☐ Ineffective ☐ Don't Know

3.5 Does the department carry out regular condition surveys for critical building elements?

☐ Always ☐ Sometimes ☐ Hardly Ever ☐ Not at all ☐ Don't Know

3.6 In terms of percentages, what % of repair and maintenance is carried out according to the following maintenance types?

No.	Maintenance Type	1-10%	11-25%	26-35%	35-50%	› 50%	N/A
1	Responsive/Reactive Maintenance						
2	Preventative Maintenance						

3.7 Does the department in the course of carrying out repair and maintenance work, carry out any opportunity repairs that may arise?

☐ Always ☐ Sometimes ☐ Hardly Ever ☐ Not at all ☐ Don't Know

3.8 What productivity improvement interventions have you implemented in the maintenance department in the last 12 months?

3.9 To what extent do you agree or disagree with the following statement:

'Within our department, there remains a good opportunity to improve maintenance labour productivity'

☐ Strongly agree ☐ Agree ☐ Strongly disagree ☐ Disagree ☐ Don't know

3.10 Based on your experience, what would be the 3 most important things for your department to improve maintenance labour productivity?

Thank you.

Would like to receive the results of this survey?

☐ Yes ☐ No

Would you be willing to amplify your answers either by phone or in a meeting?

☐ Yes ☐ No

APPENDIX C1 - Sample of CDRMS Joinery Repairs Data

Job No.	Description	Total Value	Material Cost	Est. Time	SMV	Bmark Value	Labour Cost	Billed Time	PI EH	PI EH SMV	Tradesman	Completed Date	Week Day
L58005	DRAFT BRUSH REQD ON FRONT DOOR	£58.54	£10.96	£66.33	2	0.833	£47.58	1.5	0.56	1.33	2044	21/01/2013	Monday
L59414	SECURE DOOR AFTER TENANT KICKED IN.	£41.62	£8.22	£55.00	1	0.833	£33.40	1	0.79	0.95	2049	21/01/2013	Monday
L51431	NEW STOP REQ AS PER L50406 R.DEVINE	£68.98	£5.54	£66.33	2	0.833	£63.44	2	0.42	1.00	2008,2008	21/01/2013	Monday
L47686	NEW POST REQD AS PER L47390 S CARNEGIE	£178.41	£43.60	£66.33	2	0.833	£134.81	4.25	0.20	0.47	20,192,035	21/01/2013	Monday
L59461	ADJUST PLAY AT FRONT DOOR AND RENEW DRAUGHT SEALS	£71.66	£8.22	£66.33	2	0.833	£63.44	2	0.42	1.00	2044	22/01/2013	Tuesday
L54547	CHECK THRESHOLD AT FRONT DOOR.	£41.58	£9.86	£55.00	2	0.833	£31.72	1	0.83	2.00	2008	23/01/2013	Wednesday
L59891	RENEW POST,FACING AND STOPS AT KEEPER SIDE OF FRONT	£65.11	£1.67	£66.33	2	0.833	£63.44	2	0.42	1.00	2038	23/01/2013	Wednesday
L59234	VERANDAH DOOR NOT LOCKING	£121.03	£29.18	£40.00	2	0.833	£91.85	3	0.29	0.69	2301,2301	23/01/2013	Wednesday
L60822	SECURE DOOR - POLICE IN ATTENDANCE 112	£32.01	£8.22	£55.00	1	0.833	£23.79	0.75	1.11	1.33	2301	24/01/2013	Thursday
L46683	RENEW STRIKING POST AT FRONT DOOR, RENEW YALE LOCK	£181.04	£38.30	£66.33	2	0.833	£142.74	4.5	0.19	0.44	20,492,211	24/01/2013	Thursday
L56719	REPLACE LOCKSIDE DOOR POST	£88.47	£25.03	£66.33	2	0.833	£63.44	2	0.42	1.00	2008,2008	24/01/2013	Thursday
L61187	SECURE FRONT DOOR	£32.01	£8.22	£55.00	1	0.833	£23.79	0.75	1.11	1.33	2339	25/01/2013	Friday
L54899	TENANT REPORTS BEADING COMING OFF LIVINGROOM DOOR	£65.39	£9.88	£66.33	2	0.833	£55.51	1.75	0.48	1.14	2034,2034	25/01/2013	Friday
L61500	DOOR KICKED IN TENANT WILLING TO ACCEPT RECHARGE	£41.32	£7.92	£55.00	2	0.833	£33.40	1	0.79	1.90	2083	26/01/2013	Saturday
L58928	GAPS DOWN SIDE OF FRONT DOOR - FIR DRAUGHT PROOFING	£31.72	£0.00	£66.33	2	0.833	£31.72	1.00	0.83	2.00	2049	21/01/2013	Monday
L59941	RESECURE FRONT DOOR	£33.40	£0.00	£55.00	1	0.833	£33.40	1.05	0.79	0.95	2015	22/01/2013	Tuesday
L59746	TENANT KICKED IN OWN DOOR.	£15.86	£0.00	£40.00	1	0.833	£15.86	0.50	1.67	2.00	2301	22/01/2013	Tuesday
L59882	CHECK SEALS ON PATIO DOORS	£47.58	£0.00	£66.33	2	0.833	£47.58	1.50	0.56	1.33	2019	23/01/2013	Wednesday
L59718	ADJUST BACK DOOR TO STOP DRAUGHTS	£63.44	£0.00	£66.33	2	0.833	£63.44	2.00	0.42	1.00	2031	23/01/2013	Wednesday
L60204	REAR DOOR TO CLOSE NOT UNLOCKING	£31.72	£0.00	£40.00	2	0.833	£31.72	1.00	0.83	2.00	2075,2076	23/01/2013	Wednesday
L54972	NEW DOOR POST REQD AS PER L21379 R DEVINE	£47.58	£0.00	£66.33	2	0.833	£47.58	1.50	0.56	1.33	2038,2038	24/01/2013	Thursday
L59339	ADJUST 2 BEDROOM DOOR TO FIT	£79.30	£0.00	£66.33	2	0.833	£79.30	2.50	0.33	0.80	2327	24/01/2013	Thursday
L60759	SECURE DOOR AFTER BREAK-IN	£31.72	£0.00	£55.00	1	0.833	£31.72	1.00	0.83	1.00	2019	24/01/2013	Thursday
L61582	DOOR PANES BROKEN BY TENANT	£33.40	£0.00	£55.00	2	0.833	£33.40	1.05	0.79	1.90	2036	27/01/2013	Sunday
L61592	SECURE FRONT DOOR BREAKIN	£33.40	£0.00	£55.00	1	0.833	£33.40	1.05	0.79	0.95	2036	27/01/2013	Sunday
L61576	SECURE FRONT DOOR KICKED IN BY TENANT	£33.40	£0.00	£55.00	1	0.833	£33.40	1.05	0.79	0.95	2036	27/01/2013	Sunday
L74722	EASE BEDROOM DOOR NOT CLOSING	£15.86	£0.00	£66.33	2	0.833	£15.86	1.00	0.83	2.00	2003,2043	06/03/2013	Wednesday
L75280	SECURE FRONT DOOR	£15.86	£0.00	£55.00	2.00	0.833	£15.86	0.50	1.67	4.00	2301	07/03/2013	Thursday
L75527	SECURE FRONT DOOR	£15.86	£0.00	£55.00	2.00	0.833	£15.86	0.50	1.67	4.00	2044	08/03/2013	Friday
L77851	EASE AND REPAIR BACK DOOR AND AMKE GOOD	£31.72	£0.00	£66.33	2	0.833	£31.72	2.00	0.42	1.00	2021	15/03/2013	Friday
L77828	REMOVE THRESHOLD OFF DOOR , ALLOW WHEEL CHAIR	£31.72	£0.00	£66.33	2.00	0.833	£31.72	1.00	0.83	2.00	2023	15/03/2013	Friday
L78100	OFFICE DOOR JAMMING IN CIMPLEX.	£15.86	£0.00	£40.00	1.00	0.833	£15.86	0.50	1.67	2.00	2015	15/03/2013	Friday

L78225	SECURE FRONT DOOR	£15.86	£0.00	£55.00	2.00	0.833	£15.86	0.50	1.67	4.00	2015	15/03/2013	Friday
L78224	EASE/ADJUST/REPAIR BACK DOOR	£23.79	£0.00	£66.33	2	0.833	£23.79	1.50	0.56	1.33	2023,2023	01/04/2013	Monday
L71674	JOINER REFIT SLIDING DOOR IN KITCHEN	£47.58	£0.00	£66.33	2	0.833	£47.58	3.00	0.28	0.67	2021,2049	02/04/2013	Tuesday
L79642	RENEW VESTIBULE DOOR/SURROUNDS	£15.86	£0.00	£81.14	2.00	0.833	£15.86	0.50	1.67	4.00	2023	02/04/2013	Tuesday
L73226	REMOVE & FIT DRAUGHT STRIP AT BACK DOOR	£15.86	£0.00	£55.00	2.00	0.833	£15.86	0.50	1.67	4.00	2034	02/04/2013	Tuesday
L79141	BATHROOM DOOR STICKING.	£15.86	£0.00	£66.33	2	0.833	£15.86	1.00	0.83	2.00	2043	03/04/2013	Wednesday
L77898	RENEW FRONT DOOR TRESHOLD	£7.93	£0.00	£55.00	2.00	0.833	£7.93	0.25	3.33	8.00	2021	05/04/2013	Friday
L87039	REHANG FRONT DOOR AFTER	£39.38	£7.66	£40.00	2	0.833	£31.72	2.00	0.42	1.00	2339	12/04/2013	Friday
L87135	BATHROOM DOOR NOT CLOSING PROPERLY	£61.45	£14.95	£66.33	2	0.833	£46.50	2.93	0.28	0.68	2041	15/04/2013	Monday
L86711	REHANG FRONT DOOR FOR NEW TENANT	£63.44	£0.00	£55.00	2	0.833	£63.44	4.00	0.21	0.50	2044	15/04/2013	Monday
L86851	INSTALL PLASTIC DRAUGHT SEAL TO EXTERIOR DOOR	£47.97	£0.39	£55.00	2	0.833	£47.58	3.00	0.28	0.67	2041	15/04/2013	Monday
L87081	RUBBER AT THE BOTTOM OF FRONT DOOR KEEPS SLIDING AWAY	£31.72	£0.00	£55.00	2	0.833	£31.72	2.00	0.42	1.00	2043	15/04/2013	Monday
L86232	FRONT DOOR NOT CATCHING WONT STAY CLOSED UNLESS .	£31.72	£0.00	£55.00	2	0.833	£31.72	2.00	0.42	1.00	2327	15/04/2013	Monday
L84710	RENEW LATCH ON TIMBER GATE	£24.32	£0.53	£14.30	1.00	0.833	£23.79	0.75	1.11	1.33	2339	15/04/2013	Monday
L87815	SECURE DOOR	£39.22	£8.22	£55.00	1.00	0.833	£31.00	0.98	0.85	1.02	2339	15/04/2013	Monday
L87831	SECURE DOOR THAT HAS BEEN KICKED-IN	£33.40	£0.00	£55.00	1.00	0.833	£33.40	1.05	0.79	0.95	2339	15/04/2013	Monday
L87473	BARRICADE CLOSE DOOR - GLASS SMASHED	£31.72	£0.00	£55.00	2.00	0.833	£31.72	1.00	0.83	2.00	2003	15/04/2013	Monday
L86709	EASE STRIKING PLATE/KEEPER TO HALL CUPD DOOR	£111.02	£0.00	£66.33	2.00	0.833	£111.02	3.50	0.24	0.57	2327	15/04/2013	Monday
L87044	RE HANG FRONT DOOR	£31.72	£0.00	£66.33	2	0.833	£31.72	2.00	0.42	1.00	2015,2049	16/04/2013	Tuesday
L87800	BACK DOOR TO CLOSE NOT OPENING	£15.86	£0.00	£55.00	2	0.833	£15.86	1.00	0.83	2.00	2035	16/04/2013	Tuesday
L77321	EASE FRONT DOOR	£63.44	£0.00	£66.33	2	0.833	£63.44	4.00	0.21	0.50	2043	16/04/2013	Tuesday
L88056	REAR DOOR TO CLOSE IS JAMMED	£47.58	£0.00	£40.00	2	0.833	£47.58	3.00	0.28	0.67	2044	16/04/2013	Tuesday
L87978	EASE/REPAIR DOOR, WONT LOCK	£15.86	£0.00	£40.00	2	0.833	£15.86	1.00	0.83	2.00	2301	16/04/2013	Tuesday
L87869	WORK ON POST AND YALE REQUIRED PER SHAUN	£63.44	£0.00	£40.00	2.00	0.833	£63.44	2.00	0.42	1.00	2041	16/04/2013	Tuesday
L87769	REMOVE STEEL AND REHANG	£40.81	£17.02	£43.43	2.00	0.833	£23.79	0.75	1.11	2.67	2301	16/04/2013	Tuesday
L86688	SNIB ON YALE LOCK VERY HARD TO MOVE UP AND DOWN	£40.52	£8.80	£55.00	2.00	0.833	£31.72	1.00	0.83	2.00	2327	16/04/2013	Tuesday
L88302	SECURE FRONT DOOR	£33.40	£0.00	£55.00	2.00	0.833	£33.40	1.05	0.79	1.90	2015	16/04/2013	Tuesday
L88328	BOARD PANE FRONT DOOR	£33.40	£0.00	£55.00	2.00	0.833	£33.40	1.05	0.79	1.90	2015	16/04/2013	Tuesday
L88052	SECURE FRONT DOOR	£39.94	£8.22	£55.00	2.00	0.833	£31.72	1.00	0.83	2.00	2043	16/04/2013	Tuesday
L87464	REPAIR KIT UNIT DOOR AS REQD	£61.52	£13.94	£90.00	2	0.833	£47.58	3.00	0.28	0.67	2034	17/04/2013	Wednesday
L89759	REAR DOOR TO CLOSE IS JAMMED	£31.72	£0.00	£40.00	2	0.833	£31.72	2.00	0.42	1.00	2044	17/04/2013	Wednesday
L88427	SECURE FRONT DOOR ATTEMPTED BREAKIN	£32.01	£8.22	£55.00	1.00	0.833	£23.79	0.75	1.11	1.33	2339	17/04/2013	Wednesday
L86256	NEW FACING AND YALE REQUIRED ON INSIDE OF FRONT DOOR	£91.03	£27.59	£66.33	2.00	0.833	£63.44	2.00	0.42	1.00	2340	17/04/2013	Wednesday
L81648	RENEW DRAUGHT STRIP ALL AROUND FRONT DOOR	£89.10	£9.80	£55.00	2.00	0.833	£79.30	2.50	0.33	0.80	2443	17/04/2013	Wednesday

APPENDIX C2 - Sample of CDRMS Electrical Repairs Data

Job No.	Description	Total Value	Material Cost	Est. Time	SMV	Bmark Value	Labour Cost	Billed Time	PI EH	PI EH SMV	Tradesman	Completed Date	Week Day
L58829	STAIR LIGHTING FAULTY	£70.36	£4.04	1.00	0.83	£40.93	£66.32	2.00	0.50	0.42	6060,6076	24/01/2013	Thursday
L38334	CHECK ELECTRICS (LIGHTING)	£16.58	£0.00	1.00	0.83	£18.51	£16.58	0.5	2	1.66	6078	05/12/2012	Saturday
L50502	RENEW PENDANT	£8.29	£0.00	1.00	0.83	£50.00	£8.29	0.25	4	3.32	6046	01/01/2013	Tuesday
L50844	CHECK ELECTRICS (LIGHTING)	£8.29	£0.00	1.00	0.83	£50.00	£8.29	0.25	4	3.32	6046	01/01/2013	Tuesday
L50416	CHECK ELECTRICS (LIGHTING)	£7.75	£0.00	1.00	0.83	£50.00	£7.75	0.23	4.3	3.6	6046	02/01/2013	Wednesday
L54090	CHECK ELECTRICS (LIGHTING)	£43.36	£1.91	1.00	0.83	£32.74	£41.45	1.25	0.8	0.66	6072,6020	16/01/2013	Wednesday
L45719	CHECK ELECTRICS (LIGHTING)	£85.92	£3.02	1.00	0.83	£32.74	£82.90	2.5	0.4	0.33	6060, 6076	16/01/2013	Wednesday
L53443	REPAIR/RENEW SECURITY LIGHTS	£127.93	£28.45	1.75	2.50	£64.22	£99.48	3.0	0.6	0.8	6008,6014	17/01/2013	Thursday
L52166	REPAIR/RENEW SECURITY LIGHTS	£75.88	£26.14	1.75	2.50	£64.22	£49.74	1.5	1.2	1.7	6073,6073	17/01/2013	Thursday
L52110	REPAIR/RENEW SECURITY LIGHTS	£149.20	£49.72	1.75	2.50	£64.22	£99.48	3.0	0.6	0.8	6073,6073	18/01/2013	Friday
L58397	STAIR LIGHTING FAULTY	£36.92	£3.76	1.00	0.83	£40.93	£33.16	1.0	1	0.83	6020	21/01/2013	Monday
L56375	RENEW PENDANT	£35.07	£1.91	1.00	0.83	£32.74	£33.16	1.0	1	0.83	6213	21/01/2013	Monday
L56988	STAIR LIGHTING FAULTY	£35.97	£2.81	1.00	0.83	£40.93	£33.16	1.0	1	0.83	6060,6076	21/01/2013	Monday
L58086	STAIR LIGHTING FAULTY	£27.40	£2.53	1.00	0.83	£40.93	£24.87	0.75	1.3	1.1	6002	21/01/2013	Monday
L57096	RENEW PENDANT	£61.87	£12.13	1.00	1.25	£32.74	£49.74	1.5	0.7	0.8	6213	21/01/2013	Monday
L55956	STAIR LIGHTING FAULTY	£27.40	£2.53	1.00	0.83	£40.93	£24.87	0.75	1.3	1.1	6002	21/01/2013	Monday
L57815	STAIR LIGHTING FAULTY	£41.52	£0.07	1.00	0.83	£40.93	£41.45	1.25	0.8	0.66	6002	21/01/2013	Monday
L56955	CHECK ELECTRICS (LIGHTING)	£35.97	£2.81	1.00	0.83	£40.93	£33.16	1	1	0.83	6060,6076	21/01/2013	Monday
L56190	STAIR LIGHTING FAULTY	£35.17	£2.01	1.00	0.83	£40.93	£33.16	1	1	0.83	6060,6076	21/01/2013	Monday
L58642	RENEW PENDANT	£19.98	£3.40	1.00	0.83	£50.00	£16.58	0.5	2	1.66	6014	21/01/2013	Monday
L58140	STAIR LIGHTING FAULTY	£23.40	£6.82	1.00	0.83	£40.93	£16.58	0.5	2	1.66	6014	21/01/2013	Monday
L58455	CHECK ELECTRICS (LIGHTING)	£20.32	£3.74	1.00	0.83	£40.93	£16.58	0.5	2	1.66	6008	21/01/2013	Monday
L56501	CHECK ELECTRICS (LIGHTING)	£35.97	£2.81	1.00	0.83	£40.93	£33.16	1	1	0.83	6060,6076	21/01/2013	Monday
L54107	CHECK ELECTRICS (LIGHTING)	£66.61	£16.87	1.00	0.83	£40.93	£49.74	1.5	0.7	0.6	6060,6076	21/01/2013	Monday
L55923	STAIR LIGHTING FAULTY	£35.97	£2.81	1.00	0.83	£40.93	£33.16	1	1	0.83	6060,6076	21/01/2013	Monday
L51402	REPAIR/RENEW SECURITY LIGHTS	£36.90	£3.74	1.75	2.50	£64.22	£33.16	1	1.8	2.5	6016	21/01/2013	Monday
L53476	REPAIR/RENEW SECURITY LIGHTS	£19.98	£3.40	1.75	2.50	£64.22	£16.58	0.5	3.5	5	6014	21/01/2013	Monday
L55763	STAIR LIGHTING FAULTY	£35.97	£2.81	1.00	0.83	£40.93	£33.16	1	1	0.83	6060,6076	21/01/2013	Monday
L52549	STAIR LIGHTING FAULTY	£27.52	£2.65	1.00	0.83	£40.93	£24.87	0.75	1.3	1.1	6002	21/01/2013	Monday
L56344	STAIR LIGHTING FAULTY	£35.97	£2.81	1.00	0.83	£40.93	£33.16	1	1	0.83	6060,6076	21/01/2013	Monday
L54793	STAIR LIGHTING FAULTY	£27.40	£2.53	1.00	0.83	£40.93	£24.87	0.75	1.3	1.1	6002	21/01/2013	Monday

L58617	STAIR LIGHTING FAULTY	£29.28	£4.41	1.00	0.83	£40.93	£24.87	0.75	1.3	1.1	6008	21/01/2013	Monday
L56601	STAIR LIGHTING FAULTY	£116.31	£16.83	1.00	0.83	£40.93	£99.48	3	0.3	0.3	6060,6076	21/01/2013	Monday
L58800	CHECK ELECTRICS (LIGHTING)	£24.87	£0.00	1.00	0.83	£50.00	£24.87	0.75	1.3	1.1	6008	21/01/2013	Monday
L57425	CHECK ELECTRICS (LIGHTING)	£49.74	£0.00	1.00	0.83	£32.74	£49.74	1.5	0.7	0.6	6213	21/01/2013	Monday
L56333	STAIR LIGHTING FAULTY	£82.90	£0.00	1.00	0.83	£40.93	£82.90	2.5	0.4	0.33	6060,6076	21/01/2013	Monday
L59006	CHECK ELECTRICS (LIGHTING)	£24.87	£0.00	1.00	0.83	£50.00	£24.87	0.75	1.3	1.1	6008	21/01/2013	Monday
L57755	STAIR LIGHTING FAULTY	£16.58	£0.00	1.00	0.83	£40.93	£16.58	0.5	2	1.66	6014	21/01/2013	Monday
L52234	STAIR LIGHTING FAULTY	£35.18	£2.02	1.00	0.83	£40.93	£33.16	1	1	0.83	6060,6076	22/01/2013	Tuesday
L58924	STAIR LIGHTING FAULTY	£38.50	£5.34	1.00	0.83	£40.93	£33.16	1	1	0.83	6002	22/01/2013	Tuesday
L56702	STAIR LIGHTING FAULTY	£27.40	£2.53	1.00	0.83	£40.93	£24.87	0.75	1.3	1.1	6002	22/01/2013	Tuesday
L58372	STAIR LIGHTING FAULTY	£27.40	£2.53	1.00	0.83	£40.93	£24.87	0.75	1.3	1.1	6002	22/01/2013	Tuesday
L32902	STAIR LIGHTING FAULTY	£252.51	£202.77	1.00	0.83	£40.93	£49.74	1.5	0.7	0.6	6008,6008	22/01/2013	Tuesday
L56081	CHECK ELECTRICS (LIGHTING)	£35.18	£2.02	1.00	0.83	£40.93	£33.16	1	1	0.83	6060,6076	22/01/2013	Tuesday
L47885	CHECK ELECTRICS (LIGHTING)	£75.11	£17.08	1.00	0.83	£50.00	£58.03	1.75	0.6	0.5	6008	22/01/2013	Tuesday
L56562	CHECK ELECTRICS (LIGHTING)	£27.40	£2.53	1.00	0.83	£40.93	£24.87	0.75	1.3	1.1	6002	22/01/2013	Tuesday
L53137	STAIR LIGHTING FAULTY	£27.40	£2.53	1.00	0.83	£40.93	£24.87	0.75	1.3	1.1	6002	22/01/2013	Tuesday
L59094	RENEW PENDANT	£28.27	£3.40	1.00	0.83	£40.93	£24.87	0.75	1.3	1.1	6008	22/01/2013	Tuesday
L58717	STAIR LIGHTING FAULTY	£29.93	£5.06	1.00	0.83	£50.00	£24.87	0.75	1.3	1.1	6008	22/01/2013	Tuesday
L58280	STAIR LIGHTING FAULTY	£38.50	£5.34	1.00	0.83	£40.93	£33.16	1	1	0.83	6002	22/01/2013	Tuesday
L55243	STAIR LIGHTING FAULTY	£60.20	£10.46	1.00	0.83	£40.93	£49.74	1.5	0.7	0.6	6002	22/01/2013	Tuesday
L58482	STAIR LIGHTING FAULTY	£33.16	£0.00	1.00	0.83	£40.93	£33.16	1	1	0.83	6072	22/01/2013	Tuesday
L59751	CHECK ELECTRICS (LIGHTING)	£34.80	£0.00	1.00	0.83	£50.00	£34.80	1	1	1	6020	22/01/2013	Tuesday
L59736	CHECK ELECTRICS (LIGHTING)	£34.80	£0.00	1.00	0.83	£50.00	£34.80	1.05	1.0	0.8	6020	22/01/2013	Tuesday
L59291	CHECK ELECTRICS (LIGHTING)	£33.16	£0.00	1.00	0.83	£50.00	£33.16	1	1	0.83	6072	22/01/2013	Tuesday
L57073	STAIR LIGHTING FAULTY	£66.32	£0.00	1.00	0.83	£40.93	£66.32	2	0.5	0.42	6213	22/01/2013	Tuesday
L59478	CHECK ELECTRICS (LIGHTING)	£24.87	£0.00	1.00	0.83	£50.00	£24.87	0.75	1.3	1.1	6008	22/01/2013	Tuesday
L59551	STAIR LIGHTING FAULTY	£35.97	£2.81	1.00	0.83	£40.93	£33.16	1	1	0.83	6060,6076	23/01/2013	Wednesday
L58142	STAIR LIGHTING FAULTY	£27.40	£2.53	1.00	0.83	£40.93	£24.87	0.75	1.3	1.1	6002	23/01/2013	Wednesday
L37425	STAIR LIGHTING FAULTY	£200.63	£9.96	1.00	0.83	£40.93	£190.67	5.75	0.2	0.1	6020	23/01/2013	Wednesday
L57395	STAIR LIGHTING FAULTY	£70.36	£4.04	1.00	0.83	£40.93	£66.32	2	0.5	0.42	6060,6076	23/01/2013	Wednesday
L58447	STAIR LIGHTING FAULTY	£35.18	£2.02	1.00	0.83	£40.93	£33.16	1	1	0.83	6060,6076	23/01/2013	Wednesday
L59884	STAIR LIGHTING FAULTY	£55.35	£5.61	1.00	0.83	£40.93	£49.74	1.5	0.7	0.6	6060,6076	23/01/2013	Wednesday
L45191	CHECK ELECTRICS (LIGHTING)	£68.23	£1.91	1.00	0.83	£60.00	£66.32	2	0.5	0.42	6016	23/01/2013	Wednesday
L59832	CHECK ELECTRICS (LIGHTING)	£33.67	£0.51	1.00	0.83	£50.00	£33.16	1	1	0.83	6008	23/01/2013	Wednesday
L55889	STAIR LIGHTING FAULTY	£42.12	£8.96	1.00	0.83	£40.93	£33.16	1	1	0.83	6008,6008	23/01/2013	Wednesday
L37657	REPAIR/RENEW SECURITY LIGHTS	£76.57	£26.83	1.75	2.50	£64.22	£49.74	1.5	1.2	1.7	6077	23/01/2013	Wednesday
L51481	STAIR LIGHTING FAULTY	£66.32	£0.00	1.00	0.83	£40.93	£66.32	2	0.5	0.42	6213,6213	23/01/2013	Wednesday
L49467	CHECK ELECTRICS (LIGHTING)	£49.74	£0.00	1.00	0.83	£64.22	£49.74	1.5	0.7	0.6	6213	23/01/2013	Wednesday

L59149	CHECK ELECTRICS (LIGHTING)	£33.16	£0.00	1.00	0.83	£50.00	£33.16	1	1	0.83	6085	23/01/2013	Wednesday
L57645	STAIR LIGHTING FAULTY	£49.74	£0.00	1.00	0.83	£40.93	£49.74	1.5	0.7	0.6	6213	23/01/2013	Wednesday
L59805	STAIR LIGHTING FAULTY	£24.87	£0.00	1.00	0.83	£50.00	£24.87	0.75	1.3	1.1	6008	23/01/2013	Wednesday
L55472	REPAIR/RENEW SECURITY LIGHTS	£16.58	£0.00	1.75	2.50	£64.22	£16.58	0.5	3.5	5	6020	23/01/2013	Wednesday
L55199	STAIR LIGHTING FAULTY	£33.16	£0.00	1.00	0.83	£40.93	£33.16	1	1	0.83	6213	23/01/2013	Wednesday
L58913	STAIR LIGHTING FAULTY	£51.76	£2.02	1.00	0.83	£40.93	£49.74	1.5	0.7	0.6	6060,6076	24/01/2013	Thursday
L60367	STAIR LIGHTING FAULTY	£71.96	£5.64	1.00	0.83	£40.93	£66.32	2	0.5	0.42	6076,6077	24/01/2013	Thursday
L60406	STAIR LIGHTING FAULTY	£24.16	£7.58	1.00	0.83	£40.93	£16.58	0.5	2	1.66	6008	24/01/2013	Thursday
L60627	STAIR LIGHTING FAULTY	£41.29	£8.13	1.00	0.83	£40.93	£33.16	1	1	0.83	6020	24/01/2013	Thursday
L57441	RENEW PENDANT	£51.65	£1.91	1.00	0.83	£32.74	£49.74	1.5	0.7	0.6	6016	24/01/2013	Thursday
L56490	STAIR LIGHTING FAULTY	£35.18	£2.02	1.00	0.83	£40.93	£33.16	1	1	0.83	6060,6076	24/01/2013	Thursday
L58965	CHECK ELECTRICS (LIGHTING)	£36.56	£3.40	1.00	0.83	£40.93	£33.16	1	1	0.83	6060,6076	24/01/2013	Thursday
L58858	CHECK ELECTRICS (LIGHTING)	£18.82	£2.24	1.00	0.83	£18.15	£16.58	0.5	2	1.66	6020	24/01/2013	Thursday
L60046	CHECK ELECTRICS (LIGHTING)	£25.38	£0.51	1.00	0.83	£50.00	£24.87	0.75	1.3	1.1	6008	24/01/2013	Thursday
L57310	STAIR LIGHTING FAULTY	£80.66	£14.34	1.00	0.83	£40.93	£66.32	2	0.5	0.42	6016	24/01/2013	Thursday
L46837	CHECK ELECTRICS (LIGHTING)	£66.83	£0.51	1.00	0.83	£60.00	£66.32	2	0.5	0.42	6004,6216	24/01/2013	Thursday
L52678	REPAIR/RENEW SECURITY LIGHTS	£36.04	£2.88	1.75	2.50	£64.22	£33.16	1	1.8	2.5	6002	24/01/2013	Thursday
L58177	STAIR LIGHTING FAULTY	£35.18	£2.02	1.00	0.83	£40.93	£33.16	1	1	0.83	6060,6076	24/01/2013	Thursday
L60381	STAIR LIGHTING FAULTY	£24.87	£0.00	1.00	0.83	£40.93	£24.87	0.75	1.3	1.1	6072	24/01/2013	Thursday
L58256	CHECK ELECTRICS (LIGHTING)	£24.87	£0.00	1.00	0.83	£18.51	£24.87	1	1	1	6002	24/01/2013	Thursday
L60058	CHECK ELECTRICS (LIGHTING)	£24.87	£0.00	1.00	0.83	£50.00	£24.87	1	1	1	6008	24/01/2013	Thursday
L54999	CHECK ELECTRICS (LIGHTING)	£49.74	£0.00	1.00	0.83	£32.74	£49.74	1.5	0.7	0.6	6213	24/01/2013	Thursday
L60292	CHECK ELECTRICS (LIGHTING)	£24.87	£0.00	1.00	0.83	£50.00	£24.87	0.75	1.3	1.1	6008	24/01/2013	Thursday
L38055	CHECK ELECTRICS (LIGHTING)	£33.16	£0.00	1.00	0.83	£64.22	£33.16	1	1	0.83	6085	24/01/2013	Thursday
L60193	CHECK ELECTRICS (LIGHTING)	£24.87	£0.00	1.00	0.83	£50.00	£24.87	0.75	1.3	1.1	6008	24/01/2013	Thursday
L56572	CHECK ELECTRICS (LIGHTING)	£33.16	£0.00	1.00	0.83	£64.22	£33.16	1	1	0.83	6077	24/01/2013	Thursday
L58824	CHECK ELECTRICS (LIGHTING)	£24.87	£0.00	1.00	0.83	£40.93	£24.87	0.75	1.3	1.1	6020	24/01/2013	Thursday
L57275	STAIR LIGHTING FAULTY	£24.87	£0.00	1.00	0.83	£40.93	£24.87	0.75	1.3	1.1	6002	24/01/2013	Thursday
L60139	CHECK ELECTRICS (LIGHTING)	£24.87	£0.00	1.00	0.83	£50.00	£24.87	0.75	1.3	1.1	6008	24/01/2013	Thursday
L59519	CHECK ELECTRICS (LIGHTING)	£16.58	£0.00	1.00	0.83	£40.93	£16.58	0.5	2	1.66	6020	24/01/2013	Thursday

APPENDIX C3 - Sample of CDRMS Plumbing Data

Job No.	Description	Total Value	Material cost	Bmark Value	Est. Time	SMV	Labour Cost	Billed Time	PI EH	PI EH SMV	Tradesman	Completed Date	Day of the Week
L07463	CHOKED KITCHEN SINK	£35.81	£19.23	£39.72	1.25	0.83	£16.58	0.50	2.5	1.66	4208	02/09/2012	Monday
L20815	CLEAR CHOKED KI SINK	£36.02	£2.86	£39.72	1.25	0.83	£33.16	1.00	1.25	0.83	4208	03/10/2012	Thursday
L25865	CHOKED SHOWER TRAY.	£19.45	£2.87	£39.72	1.25	1.25	£16.58	0.50	2.5	2.5	4208	17/10/2012	Thursday
L50404	CHOKED TOILET	£16.58	£0.00	£39.72	1.25	0.83	£16.58	0.50	3	2	4208	01/01/2013	Tuesday
L58781	CHOKE AT SINK	£49.74	£0.00	£39.72	1.25	0.83	£49.74	1.50	0.83	0.55	4013	21/01/2013	Monday
L58578	CHOKED STACK	£97.32	£0.00	£76.87	1.25	0.83	£97.32	2.93	0.43	0.28	4013,2044	21/01/2013	Monday
L58958	CLEAR CHOKED WC PAN	£33.16	£0.00	£39.72	1.25	0.83	£33.16	1.00	1.25	0.83	4208	21/01/2013	Monday
L59613	CHOKE AT SINK	£33.16	£0.00	£39.72	1.25	0.83	£33.16	1.00	1.25	0.83	4013	22/01/2013	Tuesday
L59988	CHOKE AT TOILET	£34.80	£0.00	£39.72	1.25	0.83	£34.80	1.05	1	1	4009	22/01/2013	Tuesday
L59396	CHOKE AT TOILET	£33.16	£0.00	£39.72	1.25	0.83	£33.16	1.00	1	1	4017	22/01/2013	Tuesday
L59360	CHOKE AT WHB AND SHOWER TRAY	£33.16	£0.00	£39.72	1.25	1.25	£33.16	1.00	1.25	1.25	4208	22/01/2013	Tuesday
L59247	CHOKED KITCHEN SINK	£33.16	£0.00	£39.72	1.25	0.83	£33.16	1.00	1.25	0.83	4208	22/01/2013	Tuesday
L59602	CLEAR CHOKE AT BATH & WHB	£33.16	£0.00	£39.72	1.25	0.83	£33.16	1.00	1	1	4208	22/01/2013	Tuesday
L59104	TOILET CHOKED	£33.16	£0.00	£31.02	1.25	0.83	£33.16	1.00	1.25	0.83	4017	22/01/2013	Tuesday
L59899	WC CHOKED	£34.80	£0.00	£39.72	1.25	0.83	£34.80	1.05	1	1	4009	22/01/2013	Tuesday
L59717	BATH CHOKED	£33.16	£0.00	£39.72	1.25	0.83	£33.16	1.00	1.25	0.83	4208	22/01/2013	Tuesday
L60349	CHOKE AT WC PAN	£24.87	£0.00	£39.72	1.25	0.83	£24.87	0.75	1.67	1.11	4028	23/01/2013	Wednesday
L59675	CHOKE AT KITCHEN SINK	£49.74	£0.00	£39.72	1.25	0.83	£49.74	1.50	0.83	0.55	4208,4208	24/01/2013	Thursday
L60595	CHOKED BATH	£33.16	£0.00	£39.72	1.25	0.83	£33.16	1.00	1.25	0.83	4208	24/01/2013	Thursday
L60593	CHOKED KITCHEN SINK	£24.87	£0.00	£39.72	1.25	0.83	£24.87	0.75	1.67	1.11	4028	24/01/2013	Thursday
L61019	CHOKED WC PAN	£52.20	£0.00	£39.72	1.25	0.83	£52.20	1.57	0.79	0.53	4039	24/01/2013	Thursday
L59579	CHOKED WC PAN ALSO KITCHEN SINK	£52.20	£0.00	£39.72	1.25	0.83	£52.20	1.57	0.79	0.53	4016	24/01/2013	Thursday
L60922	CLEAR CHOKE AT WC PAN	£46.50	£0.00	£39.72	1.25	0.83	£46.50	1.40	0.89	0.59	4039	24/01/2013	Thursday
L60637	KITCHEN SINK CHOKED	£33.16	£0.00	£39.72	1.25	0.83	£33.16	1.00	1.25	0.83	4208	24/01/2013	Thursday
L60625	CHOKE AT WC PAN	£66.32	£0.00	£39.72	1.25	0.83	£66.32	2.00	0.63	0.42	4017	24/01/2013	Thursday
L60886	CHOKE AT BATH	£33.16	£0.00	£39.72	1.25	0.83	£33.16	1.00	1.3	0.8	4016	25/01/2013	Friday
L61061	CHOKE AT KITCHEN SINK	£16.58	£0.00	£39.72	1.25	0.83	£16.58	0.50	2.5	1.66	4208	25/01/2013	Friday
L61469	CHOKE AT TOILET	£34.80	£0.00	£39.72	1.25	0.83	£34.80	1.05	1	1	4014	25/01/2013	Friday
L61074	CHOKE KITCHEN SINK	£33.16	£0.00	£39.72	1.25	0.83	£33.16	1.00	1.25	0.83	4208	25/01/2013	Friday
L61206	CHOKED WC PAN	£34.80	£0.00	£39.72	1.25	0.83	£34.80	1.05	1	1	4014	25/01/2013	Friday
L61077	CLEAR CHOKE	£33.16	£0.00	£39.72	1.25	0.83	£33.16	1.00	1	1	4017	25/01/2013	Friday
L61433	WC PAN CHOKED AND OVERFLOWING	£34.80	£0.00	£39.72	1.25	0.83	£34.80	1.05	1	1	4014	25/01/2013	Friday
L61300	CHOKED KITCHEN SINK	£34.80	£0.00	£39.72	1.25	0.83	£34.80	1.05	1	1	4010	26/01/2013	Saturday
L61502	CHOKED SINK	£34.80	£0.00	£39.72	1.25	0.83	£34.80	1.05	1	1	4010	26/01/2013	Saturday

L61480	CHOKED TOILET	£34.80	£0.00	£39.72	1.25	0.83	£34.80	1.05	1	1	4010	26/01/2013	Saturday
L61491	CHOKED TOILET	£34.80	£0.00	£39.72	1.25	0.83	£34.80	1.05	1	1	4010	26/01/2013	Saturday
L61483	KITCHEN SINK CHOKED	£34.80	£0.00	£39.72	1.25	0.83	£34.80	1.05	1	1	4010	26/01/2013	Saturday
L61145	KITCHEN SINK CHOKED	£34.80	£0.00	£39.72	1.25	0.83	£34.80	1.05	1	1	4010	26/01/2013	Saturday
L61414	CHOKE AT BATH	£34.80	£0.00	£39.72	1.25	0.83	£34.80	1.05	1	1	4010	26/01/2013	Saturday
L61605	CHOKE AT SINK	£34.80	£0.00	£50.00	1.25	0.83	£34.80	1.05	1	1	4016	27/01/2013	Sunday
L61562	CHOKE AT SINKS AND BATH	£34.80	£0.00	£39.72	1.25	0.83	£34.80	1.05	1	1	4016	27/01/2013	Sunday
L61570	CHOKE AT TOILET	£34.80	£0.00	£39.72	1.25	0.83	£34.80	1.05	1	1	4016	27/01/2013	Sunday
L61580	CHOKE AT TOILET	£34.80	£0.00	£39.72	1.25	0.83	£34.80	1.05	1	1	4016	27/01/2013	Sunday
L75587	CLEAR CHOKE IN THE BATH	£16.58	£0.00	£39.72	1.25	0.83	£16.58	0.50	2.50	1.66	4009	08/03/2013	Friday
L76915	KITCHEN SINK BLOCKED	£16.58	£0.00	£39.72	1.25	0.83	£16.58	0.50	2.50	1.66	4037	13/03/2013	Wednesday
L77004	CHOKED SHOWER TRAY	£16.58	£0.00	£39.72	1.25	1.25	£16.58	0.50	2.50	2.50	4208	13/03/2013	Wednesday
L77987	ASSIST PLUMBER AT CHOKE	£91.44	£0.00	£60.00	1.25	0.83	£91.44	2.76	0.45	0.30	1590	15/03/2013	Friday
L78035	TOILET BACKING UP - CHECK STACK	£31.82	£0.00	£88.33	1.25	0.83	£31.82	0.96	1.30	0.86	1590,4028	15/03/2013	Friday
L79407	CHOKE AT SINK	£16.58	£0.00	£39.72	1.25	0.83	£16.58	0.50	2.50	1.66	4208	02/04/2013	Tuesday
L86200	CHOKED WC P-AN AND WH BASIN	£47.25	£14.09	£39.72	1.25	0.83	£33.16	1.00	1.25	0.83	4208	10/04/2013	Sunday
L87385	SHOWER TRAY CHOKED	£33.16	£0.00	£39.72	1.25	1.25	£33.16	1.00	1.25	1.25	4006	15/04/2013	Monday
L87426	SHOWER	£33.16	£0.00	£39.72	1.25	1.25	£33.16	1.00	1.25	1.25	4006	15/04/2013	Monday
L87441	CHOKE AT BATH	£41.45	£0.00	£39.72	1.25	0.83	£41.45	1.25	1.00	0.66	4013	15/04/2013	Monday
L87396	CHOKE AT WC PAN	£82.90	£0.00	£39.72	1.25	0.83	£82.90	2.50	0.50	0.33	4016	15/04/2013	Monday
L87486	CHOKED WC PAN	£24.87	£0.00	£39.72	1.25	0.83	£24.87	0.75	1.67	1.11	4028	15/04/2013	Monday
L87498	KITCHEN SINK CHOKED	£140.93	£0.00	£39.72	1.25	0.83	£140.93	4.25	0.29	0.20	4028,4013	15/04/2013	Monday
L87395	CHOKED WC PAN	£33.16	£0.00	£39.72	1.25	0.83	£33.16	1.00	1.25	0.83	4208	15/04/2013	Monday
L87816	CHOKE AT TOILET	£34.80	£0.00	£39.72	1.25	0.83	£34.80	1.05	1.19	0.79	4208	15/04/2013	Monday
L87826	CHOKE AT TOILET	£34.80	£0.00	£39.72	1.25	0.83	£34.80	1.05	1.19	0.79	4208	15/04/2013	Monday
L88176	LEAK AT KITCHEN SINK	£33.16	£0.00	£50.00	1.25	0.83	£33.16	1.00	1.25	0.83	4009	16/04/2013	Tuesday
L88014	CHOKED BATH	£64.98	£0.00	£88.33	1.25	0.83	£64.98	1.96	0.64	0.42	1590,4013	16/04/2013	Tuesday
L87885	CHOKED KITCHEN SINK	£66.32	£0.00	£39.72	1.25	0.83	£66.32	2.00	0.63	0.42	4006	16/04/2013	Tuesday
L87787	WALK IN SHOWER CHOKED.	£33.16	£0.00	£39.72	1.25	1.25	£33.16	1.00	1.25	1.25	4009	16/04/2013	Tuesday
L87986	CHOKED KITCHEN SINK	£33.16	£0.00	£39.72	1.25	0.83	£33.16	1.00	1.25	0.83	4009	16/04/2013	Tuesday
L87801	CHOKED SINK IN BATHROOM	£16.58	£0.00	£39.72	1.25	0.83	£16.58	0.50	2.50	1.66	4017	16/04/2013	Tuesday
L87961	CHOKE AT SINK	£33.16	£0.00	£39.72	1.25	0.83	£33.16	1.00	1.25	0.83	4028	16/04/2013	Tuesday
L88015	CLEAR CHOKED WHB	£24.87	£0.00	£39.72	1.25	0.83	£24.87	0.75	1.67	1.11	4028	16/04/2013	Tuesday
L88210	CHOKED WC PAN	£52.20	£0.00	£39.72	1.25	0.83	£52.20	1.57	0.79	0.53	4033	16/04/2013	Tuesday
L88028	CHOKE AT SINK	£33.16	£0.00	£39.72	1.25	0.83	£33.16	1.00	1.25	0.83	4208	16/04/2013	Tuesday
L88133	WH BASIN STILL CHOKED	£33.16	£0.00	£39.72	1.25	0.83	£33.16	1.00	1.25	0.83	4208	16/04/2013	Tuesday
L88452	CHOKED WC PAN	£49.74	£0.00	£39.72	1.25	0.83	£49.74	1.50	0.83	0.55	4009	17/04/2013	Wednesday
L88319	CHOKE AT BATH AND SINK	£93.00	£0.00	£39.72	1.25	0.83	£93.00	2.80	0.45	0.30	4013	17/04/2013	Wednesday

APPENDIX C4 - Sample of HMS Joinery Repairs Data

Order Number	SoR Description	Total Value	SoR Est SMV	Est. Time (hours)	Total Time	Total Time	PI EH	Operative ID	Travel Time	Risk Assess Time	Repair Time	Week Day	SoR Code	Completed Date
367868	THRESHOLD:RENEW OR REFIX TO DOOR OPENING	31.38	50	0.83	0.95	00:57:01	0.88	LEE003	00:19:56	00:05:55	00:31:10	Monday	CAR084	25/11/2013 14:07
367953	DOOR:REPAIR UPVC DOOR AND / OR RENEW FITTINGS.	53.7	75	1.25	0.38	00:23:01	3.29	MCF012	00:05:34	00:10:00	00:07:27	Monday	CAR035	25/11/2013 16:19
368179	DOOR:REPAIR TIMBER DOOR AND / OR RENEW FITTINGS.	34.96	50	0.83	2.13	02:08:23	0.39	LEE003	00:00:10	00:25:16	01:42:57	Wednesday	CAR033	27/11/2013 10:39
368190	DOOR:REPAIR TIMBER DOOR AND / OR RENEW FITTINGS.	34.96	50	0.83	0.83	00:50:41	1.00	MCF012	00:12:11	00:02:32	00:35:58	Wednesday	CAR033	27/11/2013 15:14
368179	DOOR:REPAIR TIMBER DOOR AND / OR RENEW FITTINGS.	34.96	50	0.83	1.33	01:20:08	0.63	LEE003	00:50:43	00:00:22	00:29:03	Wednesday	CAR033	27/11/2013 16:19
366797	THRESHOLD:RENEW OR REFIX TO DOOR OPENING	31.38	50	0.83	1.32	01:19:26	0.63	MCF012	00:15:14	00:17:25	00:46:47	Thursday	CAR084	28/11/2013 09:09
368151	DOOR:REPAIR TIMBER DOOR AND / OR RENEW FITTINGS.	34.96	50	0.83	0.65	00:39:28	1.28	MCF012	00:03:38	00:00:43	00:35:07	Thursday	CAR033	28/11/2013 10:36
367803	WEATHERSTRIP/DRAUGHTPROOF:RENEW OR REFIX STRIPS	63.21	50	0.83	1.52	01:31:39	0.55	MCF012	00:14:22	00:03:35	01:13:42	Thursday	CAR103	28/11/2013 12:27
368387	DOOR:REPAIR TIMBER DOOR AND / OR RENEW FITTINGS.	34.96	50	0.83	1.05	01:03:11	0.79	MCF012	00:19:26	00:00:54	00:42:51	Thursday	CAR033	28/11/2013 14:42
368311	DOOR:REPAIR TIMBER DOOR AND / OR RENEW FITTINGS.	34.96	50	0.83	0.38	00:23:17	2.19	MCF012	00:09:41	00:02:20	00:11:16	Thursday	CAR033	28/11/2013 16:12
368284	DOOR:REPAIR TIMBER DOOR AND / OR RENEW FITTINGS.	34.96	50	0.83	0.97	00:58:36	0.86	LEE003	00:05:03	00:14:18	00:39:15	Thursday	CAR033	28/11/2013 16:30
368414	DOOR:REPAIR TIMBER DOOR AND / OR RENEW FITTINGS.	34.96	50	0.83	1.53	01:32:47	0.54	LEE003	00:21:12	00:01:02	01:10:33	Friday	CAR033	29/11/2013 10:46
368493	WEATHERSTRIP/DRAUGHTPROOF:RENEW OR REFIX STRIPS	63.21	50	0.83	0.27	00:16:59	3.09	TRE002	00:15:18	00:00:15	00:01:26	Friday	CAR103	29/11/2013 15:00
368260	DOOR:REPAIR TIMBER DOOR AND / OR RENEW FITTINGS.	209.8	50	0.83	2.38	02:23:16	0.35	MCF012	00:13:17	00:01:47	02:08:12	Monday	CAR033	02/12/2013 10:15
368033	FRAME:REPAIR EXTERNAL DOOR FRAME	100.1	75	1.25	2.9	02:54:07	0.43	LEE003	00:12:17	00:10:13	02:31:37	Monday	CAR047	02/12/2013 11:12
368555	DOOR:REPAIR TIMBER DOOR AND / OR RENEW FITTINGS.	34.96	50	0.83	2.62	02:37:17	0.32	MCF012	00:07:51	00:00:19	02:29:07	Monday	CAR033	02/12/2013 15:31
368573	DOOR:REPAIR TIMBER DOOR AND / OR RENEW FITTINGS.	34.96	50	0.83	0.43	00:26:01	1.94	MCF012	00:08:22	00:01:12	00:16:27	Monday	CAR033	02/12/2013 16:43
368894	DOOR:REPAIR TIMBER DOOR AND / OR RENEW FITTINGS.	34.96	50	0.83	1.73	01:44:51	0.48	TRE002	00:05:23	00:01:28	01:38:00	Wednesday	CAR033	04/12/2013 13:10

368949	DOOR:REPAIR TIMBER DOOR AND / OR RENEW FITTINGS.	69.92	50	0.83	1.17	01:10:44	0.71	TRE002	00:06:42	00:22:38	00:41:24	Wednesday	CAR03 3	04/12/2013 14:47
369011	DOOR:REPAIR TIMBER DOOR AND / OR RENEW FITTINGS.	34.96	50	0.83	0.88	00:53:05	0.95	LEE003	00:20:04	00:12:31	00:20:30	Wednesday	CAR03 3	04/12/2013 15:01
368595	DOOR:REPAIR TIMBER DOOR AND / OR RENEW FITTINGS.	34.96	50	0.83	0.42	00:25:25	1.98	LEE003	00:00:05	00:00:19	00:25:01	Thursday	CAR03 3	05/12/2013 09:04
369087	DOOR:REPAIR TIMBER DOOR AND / OR RENEW FITTINGS.	34.96	50	0.83	0.88	00:53:22	0.95	TRE002	00:02:43	00:01:11	00:49:28	Thursday	CAR03 3	05/12/2013 11:30
369108	METER CUPBOARD:RENEW DOOR	53.57	50	0.83	1.25	01:15:55	0.67	TRE002	00:12:56	00:05:50	00:57:09	Thursday	BWK0 31	05/12/2013 15:11
369405	DOOR:REPAIR TIMBER DOOR AND / OR RENEW FITTINGS.	34.96	50	0.83	0.35	00:21:29	2.38	MCF012	00:03:55	00:01:39	00:15:55	Monday	CAR03 3	09/12/2013 11:34
369106	DOOR:REPAIR TIMBER DOOR AND / OR RENEW FITTINGS.	34.96	50	0.83	1.18	01:11:15	0.71	LEE003	00:04:46	00:12:00	00:54:29	Monday	CAR03 3	09/12/2013 16:13
369100	WEATHERSTRIP/DRAUGHTPROOF:RENEW OR REFIX STRIPS	126.4	50	0.83	0.9	00:54:26	0.93	MCF012	00:15:18	00:04:48	00:34:20	Tuesday	CAR10 3	10/12/2013 09:24
369309	DOOR:REPAIR TIMBER DOOR AND / OR RENEW FITTINGS.	34.96	50	0.83	0.68	00:41:54	1.23	LEE003	00:19:48	00:07:42	00:14:24	Tuesday	CAR03 3	10/12/2013 09:28
369506	DOOR:REPAIR TIMBER DOOR AND / OR RENEW FITTINGS.	34.96	50	0.83	1.17	01:10:11	0.71	MCF012	00:16:30	00:15:57	00:37:44	Tuesday	CAR03 3	10/12/2013 10:50
368536	DOOR:REPAIR TIMBER DOOR AND / OR RENEW FITTINGS.	34.96	50	0.83	1	01:00:27	0.83	LEE003	00:06:15	00:39:36	00:14:36	Tuesday	CAR03 3	10/12/2013 12:28
369580	DOOR:REPAIR TIMBER DOOR AND / OR RENEW FITTINGS.	34.96	50	0.83	1.88	01:53:08	0.44	MCF012	00:25:54	00:59:59	00:27:15	Tuesday	CAR03 3	10/12/2013 14:18
369314	DOOR:REPAIR TIMBER DOOR AND / OR RENEW FITTINGS.	34.96	50	0.83	2.03	02:02:54	0.41	LEE003	00:13:41	00:45:45	01:03:28	Tuesday	CAR03 3	10/12/2013 17:34
369265	DOOR:REPAIR TIMBER DOOR AND / OR RENEW FITTINGS.	69.92	50	0.83	1.25	01:15:45	0.67	TRE002	00:08:49	00:01:17	01:05:39	Wednesday	CAR03 3	11/12/2013 11:11
369718	DOOR:REPAIR TIMBER DOOR AND / OR RENEW FITTINGS.	69.92	50	0.83	2.62	02:37:48	0.32	LEE003	00:09:19	00:37:14	01:51:15	Thursday	CAR03 3	12/12/2013 15:57
369603	DOOR:REPAIR TIMBER DOOR AND / OR RENEW FITTINGS.	34.96	50	0.83	0.63	00:38:44	1.32	MCF012	00:00:12	00:02:32	00:36:00	Friday	CAR03 3	13/12/2013 13:20
368912	DOOR:REPAIR TIMBER DOOR AND / OR RENEW FITTINGS.	34.96	50	0.83	1.93	01:56:28	0.43	MCF012	00:16:35	00:06:23	01:33:30	Monday	CAR03 3	16/12/2013 10:14
369198	WEATHERSTRIP/DRAUGHTPROOF:RENEW OR REFIX STRIPS	63.21	50	0.83	0.85	00:51:09	0.98	TRE002	00:10:53	00:38:41	00:01:35	Monday	CAR10 3	16/12/2013 16:18
370100	DOOR:REPAIR TIMBER DOOR AND / OR RENEW FITTINGS.	34.96	50	0.83	0.37	00:22:08	2.25	LEE003	00:15:44	00:03:16	00:03:08	Tuesday	CAR03 3	17/12/2013 11:17
369907	WEATHERSTRIP/DRAUGHTPROOF:RENEW OR REFIX STRIPS	63.21	50	0.83	1.7	01:42:34	0.49	LEE003	00:23:50	00:06:42	01:12:02	Tuesday	CAR10 3	17/12/2013 13:12
370143	DOOR:REPAIR TIMBER DOOR AND / OR RENEW FITTINGS.	34.96	50	0.83	0.45	00:27:55	1.85	LEE003	00:09:47	00:15:54	00:02:14	Tuesday	CAR03 3	17/12/2013 15:40
368763	WEATHERSTRIP/DRAUGHTPROOF:RENEW OR REFIX STRIPS	252.8	50	0.83	1.8	01:48:45	0.46	MCF012	00:16:50	00:05:44	01:26:11	Wednesday	CAR10 3	18/12/2013 15:05

370338	DOOR:REPAIR TIMBER DOOR AND / OR RENEW FITTINGS.	34.96	50	0.83	1.37	01:22:02	0.61	MCF012	00:12:42	00:00:23	01:08:57	Thursday	CAR033	19/12/2013 09:09
369916	DOOR:REPAIR TIMBER DOOR AND / OR RENEW FITTINGS.	34.96	50	0.83	0.6	00:36:54	1.39	TRE002	00:09:02	00:26:22	00:01:30	Friday	CAR033	20/12/2013 13:54
370550	DOOR:REPAIR TIMBER DOOR AND / OR RENEW FITTINGS.	34.96	50	0.83	0.92	00:55:13	0.91	TRE002	00:10:27	00:02:17	00:42:29	Monday	CAR033	23/12/2013 10:53
370603	DOOR:REPAIR TIMBER DOOR AND / OR RENEW FITTINGS.	34.96	50	0.83	2.17	02:10:38	0.38	MCF012	00:16:52	00:09:23	01:44:23	Monday	CAR033	23/12/2013 11:48
370438	DOOR:REPAIR TIMBER DOOR AND / OR RENEW FITTINGS.	34.96	50	0.83	0.78	00:47:24	1.07	LEE003	00:07:37	00:04:03	00:35:44	Monday	CAR033	23/12/2013 15:48
370684	WEATHERSTRIP/DRAUGHTPROOF:RENEW OR REFIX STRIPS	63.21	50	0.83	1.18	01:11:11	0.71	WIL020	00:38:44	00:22:58	00:09:29	Monday	CAR103	23/12/2013 16:17
370568	DOOR:REPAIR TIMBER DOOR AND / OR RENEW FITTINGS.	34.96	50	0.83	1.18	01:11:55	0.71	MCF012	00:11:02	00:05:31	00:55:22	Tuesday	CAR033	24/12/2013 09:05
370445	DOOR:REPAIR TIMBER DOOR AND / OR RENEW FITTINGS.	34.96	50	0.83	2.38	02:23:11	0.35	TRE002	00:13:29	02:08:51	00:00:51	Tuesday	CAR033	24/12/2013 10:35
370446	THRESHOLD:RENEW OR REFIX TO DOOR OPENING	156.9	50	0.83	1.47	01:28:57	0.57	MCF012	00:10:29	00:08:44	01:09:44	Tuesday	CAR084	24/12/2013 10:40
370605	METER CUPBOARD:RENEW DOOR	53.57	50	0.83	2.33	02:20:11	0.36	LEE003	00:15:41	00:04:30	02:00:00	Tuesday	BWK031	24/12/2013 12:44
369129	DOOR:REPAIR TIMBER DOOR AND / OR RENEW FITTINGS.	34.96	50	0.83	0.77	00:46:03	1.08	LEE003	00:13:04	00:00:21	00:32:38	Friday	CAR033	03/01/2014 10:28
370809	DOOR:REPAIR TIMBER DOOR AND / OR RENEW FITTINGS.	69.92	50	0.83	1.58	01:35:59	0.53	WIL020	00:21:24	01:02:19	00:12:16	Monday	CAR033	06/01/2014 09:02
370775	DOOR:REPAIR TIMBER DOOR AND / OR RENEW FITTINGS.	69.92	50	0.83	0.53	00:32:38	1.57	MCF012	00:15:55	00:04:46	00:11:57	Monday	CAR033	06/01/2014 09:04
370789	DOOR:REPAIR TIMBER DOOR AND / OR RENEW FITTINGS.	34.96	50	0.83	0.65	00:39:39	1.28	WIL020	00:20:38	00:05:44	00:13:17	Monday	CAR033	06/01/2014 12:02
371019	DOOR:REPAIR TIMBER DOOR AND / OR RENEW FITTINGS.	34.96	50	0.83	0.65	00:39:28	1.28	WIL020	00:06:26	00:21:32	00:11:30	Monday	CAR033	06/01/2014 13:24
370974	WEATHERSTRIP/DRAUGHTPROOF:RENEW OR REFIX STRIPS	63.21	50	0.83	0.83	00:50:21	1.00	MCF012	00:10:50	00:01:44	00:37:47	Monday	CAR103	06/01/2014 14:14
370854	DOOR:REPAIR TIMBER DOOR AND / OR RENEW FITTINGS.	34.96	50	0.83	1.75	01:45:01	0.48	WIL020	00:29:48	00:01:14	01:13:59	Monday	CAR033	06/01/2014 15:26
371083	DOOR:REPAIR TIMBER DOOR AND / OR RENEW FITTINGS.	34.96	50	0.83	1.23	01:14:39	0.68	WIL020	01:10:31	00:00:16	00:03:52	Monday	CAR033	06/01/2014 16:43
371248	DOOR:REPAIR TIMBER DOOR AND / OR RENEW FITTINGS.	34.96	50	0.83	0.8	00:48:34	1.04	MCF012	00:14:46	00:02:31	00:31:17	Tuesday	CAR033	07/01/2014 12:30
371015	DOOR:REPAIR TIMBER DOOR AND / OR RENEW FITTINGS.	34.96	50	0.83	0.88	00:53:23	0.95	MCF012	00:29:27	00:00:18	00:23:38	Tuesday	CAR033	07/01/2014 14:13
370126	WEATHERSTRIP/DRAUGHTPROOF:RENEW OR REFIX STRIPS	63.21	50	0.83	0.62	00:37:13	1.34	MCF012	00:08:30	00:05:33	00:23:10	Tuesday	CAR103	07/01/2014 15:32
371264	DOOR:REPAIR TIMBER DOOR AND / OR RENEW FITTINGS.	34.96	50	0.83	1.25	01:15:42	0.67	WIL020	00:21:30	00:18:51	00:35:21	Wednesday	CAR033	08/01/2014 16:32

371455	DOOR:REPAIR TIMBER DOOR AND / OR RENEW FITTINGS.	34.96	50	0.83	0.57	00:34:52	1.46	MCF012	00:00:03	00:00:47	00:34:02	Thursday	CAR033	09/01/2014 09:53
371471	DOOR:REPAIR TIMBER DOOR AND / OR RENEW FITTINGS.	34.96	50	0.83	1.52	01:31:44	0.55	WIL020	00:07:09	00:06:11	01:18:24	Thursday	CAR033	09/01/2014 10:08
371514	DOOR:REPAIR TIMBER DOOR AND / OR RENEW FITTINGS.	34.96	50	0.83	0.65	00:39:55	1.28	MCF012	00:14:30	00:00:28	00:24:57	Thursday	CAR033	09/01/2014 12:17
371511	DOOR:REPAIR TIMBER DOOR AND / OR RENEW FITTINGS.	34.96	50	0.83	1.55	01:33:26	0.54	WIL020	00:17:06	00:00:19	01:16:01	Thursday	CAR033	09/01/2014 12:51
371532	DOOR:REPAIR TIMBER DOOR AND / OR RENEW FITTINGS.	34.96	50	0.83	0.43	00:26:53	1.94	WIL020	00:16:30	00:08:31	00:01:52	Thursday	CAR033	09/01/2014 13:22
371502	DOOR:REPAIR TIMBER DOOR AND / OR RENEW FITTINGS.	34.96	50	0.83	1.33	01:20:32	0.63	LEE003	00:09:25	01:05:58	00:05:09	Thursday	CAR033	09/01/2014 13:28
371552	DOOR:REPAIR TIMBER DOOR AND / OR RENEW FITTINGS.	34.96	50	0.83	0.67	00:40:48	1.24	LEE003	00:19:23	00:00:24	00:21:01	Thursday	CAR033	09/01/2014 14:14
371560	DOOR:REPAIR TIMBER DOOR AND / OR RENEW FITTINGS.	34.96	50	0.83	0.63	00:38:31	1.32	LEE003	00:01:11	00:04:34	00:32:46	Thursday	CAR033	09/01/2014 15:21
371166	DOOR:REPAIR TIMBER DOOR AND / OR RENEW FITTINGS.	34.96	50	0.83	0.22	00:13:02	3.79	WIL020	00:00:03	00:00:20	00:12:39	Thursday	CAR033	09/01/2014 15:26
371572	DOOR:REPAIR TIMBER DOOR AND / OR RENEW FITTINGS.	34.96	50	0.83	0.18	00:11:35	4.63	LEE003	00:00:09	00:00:17	00:11:09	Thursday	CAR033	09/01/2014 15:40
371340	DOOR:REPAIR TIMBER DOOR AND / OR RENEW FITTINGS.	34.96	50	0.83	0.9	00:54:07	0.93	WIL020	00:13:01	00:00:16	00:40:50	Thursday	CAR033	09/01/2014 16:38
371377	DOOR:REPAIR TIMBER DOOR AND / OR RENEW FITTINGS.	34.96	50	0.83	1.02	01:01:19	0.82	WIL020	00:26:18	00:00:15	00:34:46	Friday	CAR033	10/01/2014 09:08
371573	DOOR:REPAIR TIMBER DOOR AND / OR RENEW FITTINGS.	34.96	50	0.83	0.38	00:23:14	2.19	WIL020	00:10:18	00:10:35	00:02:21	Friday	CAR033	10/01/2014 09:33
371593	WEATHERSTRIP/DRAUGHTPROOF:RENEW OR REFIX STRIPS	63.21	50	0.83	1.1	01:06:51	0.76	TRE002	00:14:28	00:51:37	00:00:46	Friday	CAR103	10/01/2014 09:36
371621	DOOR:REPAIR TIMBER DOOR AND / OR RENEW FITTINGS.	34.96	50	0.83	0.82	00:49:21	1.02	TRE002	00:10:08	00:02:08	00:37:05	Friday	CAR033	10/01/2014 10:26
371659	DOOR:REPAIR TIMBER DOOR AND / OR RENEW FITTINGS.	34.96	50	0.83	0.65	00:39:02	1.28	WIL020	00:20:10	00:18:10	00:00:42	Friday	CAR033	10/01/2014 11:58
371636	DOOR:REPAIR TIMBER DOOR AND / OR RENEW FITTINGS.	34.96	50	0.83	0.77	00:46:21	1.08	TRE002	00:00:03	00:06:00	00:40:18	Friday	CAR033	10/01/2014 13:03
371729	DOOR:REPAIR TIMBER DOOR AND / OR RENEW FITTINGS.	34.96	50	0.83	0.38	00:23:57	2.19	MCF012	00:04:48	00:02:03	00:17:06	Friday	CAR033	10/01/2014 14:03
371699	DOOR:REPAIR TIMBER DOOR AND / OR RENEW FITTINGS.	34.96	50	0.83	1.9	01:54:22	0.44	LEE003	00:06:25	00:15:22	01:32:35	Friday	CAR033	10/01/2014 15:07
371124	DOOR:REPAIR TIMBER DOOR AND / OR RENEW FITTINGS.	34.96	50	0.83	0.53	00:32:55	1.57	MCF012	00:07:03	00:03:48	00:22:04	Monday	CAR033	13/01/2014 09:30
371611	DOOR:REPAIR TIMBER DOOR AND / OR RENEW FITTINGS.	139.8	50	0.83	2.22	02:13:11	0.38	WIL020	00:10:40	00:11:09	01:51:22	Monday	CAR033	13/01/2014 09:49
371524	DOOR:REPAIR TIMBER DOOR AND / OR RENEW FITTINGS.	34.96	50	0.83	0.93	00:56:00	0.90	LEE003	00:18:42	00:09:20	00:27:58	Monday	CAR033	13/01/2014 10:35

371295	METER CUPBOARD:RENEW DOOR	53.57	50	0.83	0.82	00:49:32	1.02	TRE002	00:05:15	00:00:48	00:43:29	Monday	BWK031	13/01/2014 10:53
371842	DOOR:REPAIR TIMBER DOOR AND / OR RENEW FITTINGS.	34.96	50	0.83	1.05	01:03:30	0.79	MCF012	00:08:45	00:00:26	00:54:19	Monday	CAR033	13/01/2014 14:20
371839	DOOR:REPAIR TIMBER DOOR AND / OR RENEW FITTINGS.	34.96	50	0.83	0.33	00:20:47	2.53	MCF012	00:06:38	00:13:30	00:00:39	Monday	CAR033	13/01/2014 14:42
371331	WEATHERSTRIP/DRAUGHTPROOF:RENEW OR REFIX STRIPS	316.1	50	0.83	1.18	01:11:29	0.71	TRE002	00:05:56	00:00:13	01:05:20	Monday	CAR103	13/01/2014 15:04
371482	DOOR:REPAIR TIMBER DOOR AND / OR RENEW FITTINGS.	34.96	50	0.83	0.33	00:20:35	2.53	MCF012	00:08:34	00:04:23	00:07:38	Monday	CAR033	13/01/2014 15:13
371183	DOOR:REPAIR TIMBER DOOR AND / OR RENEW FITTINGS.	69.92	50	0.83	2.18	02:11:55	0.38	LEE003	00:14:02	00:00:22	01:57:31	Monday	CAR033	13/01/2014 15:46
371260	FRAME:REPAIR EXTERNAL DOOR FRAME	33.35	75	1.25	0.82	00:49:51	1.52	WIL020	00:21:26	00:03:29	00:24:56	Tuesday	CAR047	14/01/2014 08:20
371720	DOOR:REPAIR TIMBER DOOR AND / OR RENEW FITTINGS.	34.96	50	0.83	0.37	00:22:02	2.25	WIL020	00:08:40	00:00:15	00:13:07	Tuesday	CAR033	14/01/2014 11:28
371896	WEATHERSTRIP/DRAUGHTPROOF:RENEW OR REFIX STRIPS	126.4	50	0.83	0.37	00:22:23	2.25	WIL020	00:00:02	00:20:28	00:01:53	Tuesday	CAR103	14/01/2014 12:47
371456	FRAME:REPAIR EXTERNAL DOOR FRAME	33.35	75	1.25	0.67	00:40:37	1.87	MCF012	00:19:02	00:05:37	00:15:58	Wednesday	CAR047	15/01/2014 08:50
371824	WEATHERSTRIP/DRAUGHTPROOF:RENEW OR REFIX STRIPS	63.21	50	0.83	0.75	00:45:13	1.11	WIL020	00:29:58	00:00:15	00:15:00	Wednesday	CAR103	15/01/2014 12:06
372013	DOOR:REPAIR TIMBER DOOR AND / OR RENEW FITTINGS.	34.96	50	0.83	0.82	00:49:42	1.02	LEE003	00:08:56	00:07:51	00:32:55	Wednesday	CAR033	15/01/2014 14:06
371964	DOOR:REPAIR TIMBER DOOR AND / OR RENEW FITTINGS.	34.96	50	0.83	0.5	00:30:07	1.67	WIL020	00:12:59	00:00:15	00:16:53	Wednesday	CAR033	15/01/2014 14:39
372124	DOOR:REPAIR TIMBER DOOR AND / OR RENEW FITTINGS.	34.96	50	0.83	1	01:00:11	0.83	LEE003	00:21:16	00:00:16	00:38:39	Wednesday	CAR033	15/01/2014 15:31
371105	DOOR:REPAIR TIMBER DOOR AND / OR RENEW FITTINGS.	34.96	50	0.83	0.67	00:40:51	1.24	LEE003	00:08:36	00:09:38	00:22:37	Wednesday	CAR033	15/01/2014 16:17
371777	DOOR:REPAIR TIMBER DOOR AND / OR RENEW FITTINGS.	69.92	50	0.83	1.42	01:25:59	0.59	TRE002	00:06:32	00:39:28	00:39:59	Wednesday	CAR033	15/01/2014 16:21

APPENDIX C5 - Sample of HMS Electrical Repairs Data

Order Number	SoR Description	Total Value	SoR Est SMV	Est. Time (hr)	Total Time (hr)		PI EH	Operative ID	Travel Time	Risk Assess Time	Repair Time	Week Day	SoR Code	Completed Date
367885	EXTERNAL LIGHTING:REPAIR EXTERNAL LIGHTING	51.28	75	1.25	1.82	01:49	0.69	BIG001	00:07:09	00:06:04	01:36:38	Monday	ELE083	25/11/2013 11:32
367929	COMMUNAL LIGHTING:REPAIR COMMUNAL LIGHTING	72.84	50	0.83	0.47	00:28	1.77	HEA002	00:07:30	00:00:37	00:20:52	Monday	ELE005	25/11/2013 11:48
367941	COMMUNAL LIGHTING:REPAIR COMMUNAL LIGHTING	72.84	50	0.83	0.73	00:44	1.14	HEA002	00:01:27	00:03:06	00:40:16	Monday	ELE005	25/11/2013 13:54
367926	LIGHTING COLUMN:OVERHAUL BOLLARD TYPE	34.06	50	0.83	0.75	00:45	1.11	HEA002	00:21:31	00:00:37	00:23:17	Monday	ELE103	25/11/2013 14:44
366574	LIGHT:REPAIR OR RENEW INTERNAL LIGHT FITTING	37.49	50	0.83	0.48	00:29	1.74	HEA002	00:19:00	00:00:31	00:09:46	Monday	ELE061	25/11/2013 15:18
367993	LIGHT FITTING:REMOVE AND REFIX ANY EXTERNAL TYPE	34.32	50	0.83	0.75	00:45	1.11	HEA002	00:25:39	00:01:09	00:19:07	Monday	ELE060	25/11/2013 16:25
367983	LIGHT:REPAIR OR RENEW INTERNAL LIGHT FITTING	112.47	50	0.83	0.62	00:37	1.34	HEA002	00:12:41	00:06:30	00:18:35	Tuesday	ELE061	26/11/2013 10:15
368068	LIGHT:RENEW LAMP, BULB OR TUBE TO LIGHT FITTING	33.6	25	0.42	0.33	00:20	1.26	HEA002	00:08:11	00:00:58	00:11:34	Tuesday	ELE059	26/11/2013 14:29
367942	LIGHT:RENEW LAMP, BULB OR TUBE TO LIGHT FITTING	33.6	25	0.42	0.3	00:18	1.39	HEA002	00:06:09	00:08:21	00:04:05	Wednesday	ELE059	27/11/2013 11:52
368021	LIGHT:RENEW LAMP, BULB OR TUBE TO LIGHT FITTING	33.6	25	0.42	0.35	00:21	1.19	HEA002	00:00:11	00:00:26	00:20:26	Wednesday	ELE059	27/11/2013 12:19
368184	COMMUNAL LIGHTING:REPAIR COMMUNAL LIGHTING	72.84	50	0.83	0.4	00:24	2.08	HEA002	00:03:41	00:00:47	00:20:12	Wednesday	ELE005	27/11/2013 15:11
368111	COMMUNAL LIGHTING:REPAIR COMMUNAL LIGHTING	72.84	50	0.83	0.28	00:17	2.98	BIG001	00:07:59	00:01:25	00:07:40	Thursday	ELE005	28/11/2013 12:54
368074	LIGHT:REPAIR OR RENEW INTERNAL LIGHT FITTING	37.49	50	0.83	0.9	00:54	0.93	BIG001	00:17:08	00:21:31	00:16:06	Thursday	ELE061	28/11/2013 13:52
368142	BATHROOM LIGHT FITTING:RENEW WITH SEALED UNIT	85.39	75	1.25	0.55	0:33	2.27	BIG001	00:04:26	00:03:35	00:25:07	Thursday	ELE062	28/11/2013 10:26
368293	LIGHT:RENEW LAMP, BULB OR TUBE TO LIGHT FITTING	67.2	25	0.42	0.23	00:14	1.81	BIG001	00:06:57	00:01:14	00:06:24	Friday	ELE059	29/11/2013 13:42
368270	LIGHT:REPAIR OR RENEW INTERNAL LIGHT FITTING	37.49	50	0.83	0.38	00:23	2.19	BIG001	00:05:48	00:09:25	00:08:19	Friday	ELE061	29/11/2013 14:19
368398	COMMUNAL LIGHTING:REPAIR COMMUNAL LIGHTING	72.84	50	0.83	0.28	00:17	2.98	BIG001	00:04:26	00:01:49	00:11:08	Friday	ELE005	29/11/2013 14:41
368440	COMMUNAL LIGHTING:REPAIR COMMUNAL LIGHTING	72.84	50	0.83	0.87	00:52	0.96	BIG001	00:03:32	00:00:41	00:48:43	Friday	ELE005	29/11/2013 15:38
368448	LIGHT:RENEW LAMP, BULB OR TUBE TO LIGHT FITTING	33.6	25	0.42	0.52	00:31	0.80	HEA002	00:15:44	00:05:30	00:10:23	Monday	ELE059	02/12/2013 08:20

368223	LIGHT:REPAIR OR RENEW INTERNAL LIGHT FITTING	37.49	50	0.83	0.75	00:45	1.11	BIG001	00:06:03	00:04:05	00:35:18	Monday	ELE061	02/12/2013 10:15
368430	LIGHT:REPAIR OR RENEW INTERNAL LIGHT FITTING	37.49	50	0.83	0.22	00:13	3.79	BIG001	00:02:49	00:06:04	00:04:24	Monday	ELE061	02/12/2013 14:31
368491	COMMUNAL LIGHTING:REPAIR COMMUNAL LIGHTING	72.84	50	0.83	0.17	00:10	4.90	BIG001	00:01:54	00:01:14	00:07:45	Monday	ELE005	02/12/2013 14:57
368565	COMMUNAL LIGHTING:REPAIR COMMUNAL LIGHTING	72.84	50	0.83	0.7	00:42	1.19	HEA002	00:05:27	00:00:30	00:37:01	Monday	ELE005	02/12/2013 16:24
368484	LIGHT:REPAIR OR RENEW INTERNAL LIGHT FITTING	37.49	50	0.83	0.88	00:53	0.95	BIG001	00:52:26	00:00:24	00:00:52	Tuesday	ELE061	03/12/2013 09:03
368582	COMMUNAL LIGHTING:REPAIR COMMUNAL LIGHTING	72.84	50	0.83	0.2	00:12	4.17	BIG001	00:03:19	00:01:17	00:07:52	Tuesday	ELE005	03/12/2013 10:54
368496	LIGHT:RENEW LAMP, BULB OR TUBE TO LIGHT FITTING	33.6	25	0.42	0.22	00:13	1.89	BIG001	00:03:53	00:01:52	00:07:22	Tuesday	ELE059	03/12/2013 11:08
368344	LIGHT:REPAIR OR RENEW INTERNAL LIGHT FITTING	37.49	50	0.83	0.65	00:39	1.28	HEA002	00:07:40	00:00:26	00:31:23	Tuesday	ELE061	03/12/2013 11:22
368538	LIGHT:REPAIR OR RENEW INTERNAL LIGHT FITTING	37.49	50	0.83	1	01:00	0.83	HEA002	00:18:09	00:09:14	00:33:17	Tuesday	ELE061	03/12/2013 12:54
368506	LIGHT:REPAIR OR RENEW INTERNAL LIGHT FITTING	37.49	50	0.83	0.42	00:25	1.98	BIG001	00:18:34	00:01:14	00:05:51	Tuesday	ELE061	03/12/2013 13:54
368156	EXTERNAL LIGHTING:REPAIR EXTERNAL LIGHTING	51.28	75	1.25	0.33	00:20	3.79	BIG001	00:04:25	00:01:14	00:14:41	Wednesday	ELE083	04/12/2013 10:38
368954	COMMUNAL LIGHTING:REPAIR COMMUNAL LIGHTING	72.84	50	0.83	0.42	00:25	1.98	HEA002	00:15:15	00:00:28	00:09:44	Wednesday	ELE005	04/12/2013 13:12
368841	COMMUNAL LIGHTING:REPAIR COMMUNAL LIGHTING	72.84	50	0.83	0.98	00:59	0.85	HEA002	00:05:05	00:00:25	00:54:14	Wednesday	ELE005	04/12/2013 16:19
369007	EXTERNAL LIGHTING:RENEW BULKHEAD FITTING	66.95	75	1.25	0.27	00:16	4.63	BIG001	00:05:25	00:00:58	00:10:19	Wednesday	ELE081	05/12/2013 14:35
369169	COMMUNAL LIGHTING:REPAIR COMMUNAL LIGHTING	72.84	50	0.83	0.82	00:49	1.02	HEA002	00:06:05	00:42:36	00:00:51	Thursday	ELE005	05/12/2013 15:14
368879	COMMUNAL LIGHTING:REPAIR COMMUNAL LIGHTING	72.84	50	0.83	0.75	00:45	1.11	HEA002	00:16:01	00:00:32	00:28:51	Thursday	ELE005	05/12/2013 16:17
369142	LIGHT:REPAIR OR RENEW INTERNAL LIGHT FITTING	37.49	50	0.83	0.2	00:12	4.17	BIG001	00:02:59	00:01:26	00:08:17	Monday	ELE061	06/12/2013 11:32
369034	COMMUNAL LIGHTING:REPAIR COMMUNAL LIGHTING	72.84	50	0.83	0.57	00:34	1.46	BIG001	00:09:10	00:00:54	00:24:40	Monday	ELE005	06/12/2013 13:10
368945	COMMUNAL LIGHTING:REPAIR COMMUNAL LIGHTING	72.84	50	0.83	1.57	01:34	0.53	BIG001	00:00:07	00:00:37	01:34:04	Thursday	ELE005	06/12/2013 14:17
368951	COMMUNAL LIGHTING:REPAIR COMMUNAL LIGHTING	72.84	50	0.83	1.07	01:04	0.78	BIG001	00:08:47	00:01:46	00:53:45	Friday	ELE005	06/12/2013 14:58
369246	LIGHT:REPAIR OR RENEW INTERNAL LIGHT FITTING	37.49	50	0.83	0.37	00:22	2.25	BIG001	00:08:31	00:02:47	00:11:31	Tuesday	ELE061	06/12/2013 15:27
368221	LIGHT:REPAIR OR RENEW INTERNAL LIGHT FITTING	74.98	50	0.83	0.58	00:35	1.44	BIG001	00:12:34	00:04:09	00:19:03	Monday	ELE061	09/12/2013 10:01
369339	COMMUNAL LIGHTING:REPAIR COMMUNAL	72.84	50	0.83	0.62	00:37	1.34	BIG001	00:03:37	00:02:43	00:31:27	Tuesday	ELE005	10/12/2013 08:44

	LIGHTING													
369209	COMMUNAL LIGHTING:REPAIR COMMUNAL LIGHTING	72.84	50	0.83	0.25	00:15	3.33	BIG001	00:03:41	00:02:48	00:09:05	Friday	ELE005	10/12/2013 09:08
368758	LIGHT:RENEW LAMP, BULB OR TUBE TO LIGHT FITTING	33.6	25	0.42	0.43	00:26	0.97	BIG001	00:05:14	00:01:43	00:19:08	Thursday	ELE059	10/12/2013 09:27
369263	LIGHT:REPAIR OR RENEW INTERNAL LIGHT FITTING	37.49	50	0.83	0.27	00:16	3.09	BIG001	00:00:07	00:01:21	00:15:30	Friday	ELE061	10/12/2013 10:20
369432	LIGHT:RENEW LAMP, BULB OR TUBE TO LIGHT FITTING	33.6	25	0.42	0.48	00:29	0.87	BIG001	00:08:55	00:02:58	00:17:08	Tuesday	ELE059	10/12/2013 13:38
369605	COMMUNAL LIGHTING:REPAIR COMMUNAL LIGHTING	72.84	50	0.83	0.65	00:39	1.28	HEA002	00:08:16	00:02:12	00:29:27	Tuesday	ELE005	10/12/2013 15:27
369600	LIGHT:REPAIR OR RENEW INTERNAL LIGHT FITTING	37.49	50	0.83	0.88	00:53	0.95	HEA002	00:02:54	00:28:40	00:21:52	Tuesday	ELE061	10/12/2013 16:28
369489	COMMUNAL LIGHTING:REPAIR COMMUNAL LIGHTING	72.84	50	0.83	0.47	00:28	1.77	BIG001	00:10:33	00:00:52	00:17:30	Tuesday	ELE005	11/12/2013 10:14
369475	LIGHT FITTING:REMOVE AND REFIX ANY EXTERNAL TYPE	34.32	50	0.83	1.33	01:20	0.63	HEA002	00:04:48	00:02:59	01:13:08	Wednesday	ELE060	11/12/2013 10:25
369306	BATHROOM LIGHT FITTING:RENEW WITH SEALED UNIT	85.39	75	1.25	0.28	0:17	4.46	BIG001	00:05:35	00:02:08	00:09:39	Tuesday	ELE062	11/12/2013 10:52
368266	COMMUNAL LIGHTING:REPAIR COMMUNAL LIGHTING	145.68	50	0.83	0.5	00:30	1.67	HEA002	00:13:53	00:00:29	00:16:06	Wednesday	ELE005	11/12/2013 14:24
369624	COMMUNAL LIGHTING:REPAIR COMMUNAL LIGHTING	72.84	50	0.83	0.3	00:18	2.78	BIG001	00:07:22	00:01:44	00:09:37	Wednesday	ELE005	11/12/2013 16:15
369644	COMMUNAL LIGHTING:REPAIR COMMUNAL LIGHTING	72.84	50	0.83	0.7	00:42	1.19	BIG001	00:05:46	00:02:38	00:33:39	Tuesday	ELE005	12/12/2013 09:32
369775	COMMUNAL LIGHTING:REPAIR COMMUNAL LIGHTING	72.84	50	0.83	0.68	00:41	1.23	HEA002	00:00:12	00:25:03	00:15:48	Thursday	ELE005	12/12/2013 11:18
369623	COMMUNAL LIGHTING:REPAIR COMMUNAL LIGHTING	72.84	50	0.83	0.17	00:10	4.90	BIG001	00:00:05	00:01:24	00:09:11	Thursday	ELE005	12/12/2013 11:20
369736	LIGHT:RENEW LAMP, BULB OR TUBE TO LIGHT FITTING	33.6	25	0.42	0.13	00:08	3.21	BIG001	00:00:09	00:06:33	00:01:32	Monday	ELE059	12/12/2013 11:37
369790	COMMUNAL LIGHTING:REPAIR COMMUNAL LIGHTING	72.84	50	0.83	0.43	00:26	1.94	HEA002	00:05:35	00:00:25	00:20:09	Thursday	ELE005	12/12/2013 13:18
369815	LIGHT:REPAIR OR RENEW INTERNAL LIGHT FITTING	37.49	50	0.83	0.55	00:33	1.52	HEA002	00:04:30	00:01:47	00:26:59	Thursday	ELE061	12/12/2013 13:53
369714	COMMUNAL LIGHTING:REPAIR COMMUNAL LIGHTING	145.68	50	0.83	0.28	00:17	2.98	BIG001	00:04:59	00:01:40	00:11:19	Monday	ELE005	13/12/2013 08:49
368254	LIGHT:RENEW LAMP, BULB OR TUBE TO LIGHT FITTING	33.6	25	0.42	0.43	00:26	0.97	BIG001	00:23:59	00:00:38	00:02:05	Friday	ELE059	13/12/2013 11:23
369469	COMMUNAL LIGHTING:REPAIR COMMUNAL LIGHTING	72.84	50	0.83	0.68	00:41	1.23	HAM011	00:00:05	00:00:34	00:40:48	Friday	ELE005	13/12/2013 11:30
369630	COMMUNAL LIGHTING:REPAIR COMMUNAL LIGHTING	72.84	50	0.83	0.35	00:21	2.38	BIG001	00:11:43	00:01:36	00:08:11	Monday	ELE005	13/12/2013 11:51

369301	LIGHT:REPAIR OR RENEW INTERNAL LIGHT FITTING	37.49	50	0.83	0.85	00:51	0.98	HAM011	00:13:05	00:08:41	00:30:08	Friday	ELE061	13/12/2013 12:23
369837	COMMUNAL LIGHTING:REPAIR COMMUNAL LIGHTING	72.84	50	0.83	0.33	00:20	2.53	HEA002	00:00:04	00:00:24	00:19:42	Friday	ELE005	13/12/2013 14:26
369624	LIGHT:REPAIR OR RENEW INTERNAL LIGHT FITTING	37.49	50	0.83	0.92	00:55	0.91	BIG001	00:03:57	00:15:22	00:35:55	Thursday	ELE061	16/12/2013 10:07
369781	COMMUNAL LIGHTING:REPAIR COMMUNAL LIGHTING	72.84	50	0.83	0.43	00:26	1.94	BIG001	00:04:14	00:15:20	00:06:48	Tuesday	ELE005	16/12/2013 12:22
369747	LIGHT:RENEW LAMP, BULB OR TUBE TO LIGHT FITTING	33.6	25	0.42	0.27	00:16	1.54	BIG001	00:00:05	00:01:00	00:15:39	Friday	ELE059	16/12/2013 13:57
369797	COMMUNAL LIGHTING:REPAIR COMMUNAL LIGHTING	72.84	50	0.83	0.4	00:24	2.08	BIG001	00:12:15	00:05:20	00:06:42	Monday	ELE005	16/12/2013 15:49
369239	EXTERNAL LIGHTING:REPAIR EXTERNAL LIGHTING	51.28	75	1.25	0.83	00:50	1.51	HEA002	00:00:07	00:05:25	00:45:10	Monday	ELE083	16/12/2013 16:41
369624	LIGHT:RENEW LAMP, BULB OR TUBE TO LIGHT FITTING	33.6	25	0.42	0.48	00:29	0.87	BIG001	00:00:24	00:00:51	00:28:07	Wednesday	ELE059	17/12/2013 10:13
369932	COMMUNAL LIGHTING:REPAIR COMMUNAL LIGHTING	72.84	50	0.83	1.05	01:03	0.79	BIG001	00:03:24	00:01:35	00:58:14	Thursday	ELE005	17/12/2013 13:55
369902	COMMUNAL LIGHTING:REPAIR COMMUNAL LIGHTING	72.84	50	0.83	0.37	00:22	2.25	BIG001	00:12:44	00:01:17	00:08:54	Tuesday	ELE005	17/12/2013 16:20
369793	COMMUNAL LIGHTING:REPAIR COMMUNAL LIGHTING	72.84	50	0.83	0.85	00:51	0.98	BIG001	00:07:36	00:02:05	00:41:27	Monday	ELE005	18/12/2013 09:55
370201	LIGHT:RENEW LAMP, BULB OR TUBE TO LIGHT FITTING	33.6	25	0.42	0.78	00:47	0.53	HEA002	00:15:54	00:06:06	00:25:22	Wednesday	ELE059	18/12/2013 10:56
370135	LIGHT:REPAIR OR RENEW INTERNAL LIGHT FITTING	37.49	50	0.83	0.62	00:37	1.34	HEA002	00:10:38	00:03:06	00:24:11	Wednesday	ELE061	18/12/2013 14:01
370047	LIGHT:RENEW LAMP, BULB OR TUBE TO LIGHT FITTING	33.6	25	0.42	0.52	00:31	0.80	BIG001	00:07:53	00:02:21	00:21:26	Wednesday	ELE059	19/12/2013 12:14
370015	COMMUNAL LIGHTING:REPAIR COMMUNAL LIGHTING	72.84	50	0.83	0.37	00:22	2.25	BIG001	00:11:59	00:00:50	00:09:39	Friday	ELE005	19/12/2013 13:24
370047	COMMUNAL LIGHTING:REPAIR COMMUNAL LIGHTING	72.84	50	0.83	0.8	00:48	1.04	BIG001	00:12:04	00:03:59	00:31:59	Friday	ELE005	19/12/2013 16:29

APPENDIX C6 - Sample of HMS Plumbing Repairs Data

Order Number	SoR Description	Total Value	SoR Est SMV	Est. T (hrs)	Total T (hrs)	Total Time	PI EH	Operative ID	Travel Time	Risk Assess Time	Repair Time	Week Day	SoR Code	Completed Date
384099	DRAIN:CLEAR BLOCKAGE TO GULLY/DRAIN	27.18	50	0.83	0.62	0:37:02	1.34	SLO001	00:12:15	00:00:43	00:24:04	Monday	GRD047	25/11/2013 12:05
367382	SINK:CLEAR BLOCKAGE	32.04	50	0.83	1.17	1:10:09	0.71	SLO001	00:18:12	00:06:54	00:45:03	Monday	PLU046	25/11/2013 16:02
367961	SHOWER:CLEAR BLOCKAGE INCLUDING REMOVE	39.85	75	1.25	0.5	0:30:03	2.50	SLO001	00:11:16	00:02:34	00:16:13	Thursday	PLU034	28/11/2013 13:25
376082	SHOWER:CLEAR BLOCKAGE INCLUDING REMOVE	39.85	75	1.25	1.92	1:55:24	0.65	THO019	00:09:13	01:43:08	00:03:03	Thursday	PLU034	05/12/2013 13:08
384170	BASIN:CLEAR BLOCKAGE	33.16	50	0.83	0.77	0:46:26	1.08	SLO001	00:26:25	00:01:48	00:18:13	Wednesday	PLU002	11/12/2013 11:25
369131	DRAIN:CLEAR BLOCKAGE TO GULLY/DRAIN	52.52	50	0.83	0.62	0:37:01	1.34	THO019	00:11:37	00:00:21	00:25:03	Tuesday	GRD047	17/12/2013 08:27
381030	SHOWER:CLEAR BLOCKAGE INCLUDING REMOVE	41.24	75	1.25	0.48	0:29:56	2.60	MIL026	00:11:17	00:15:22	00:03:17	Wednesday	PLU034	18/12/2013 13:57
369948	BASIN:CLEAR BLOCKAGE	32.04	50	0.83	0.85	0:51:15	0.98	THO019	00:04:49	00:01:52	00:44:34	Wednesday	PLU002	18/12/2013 14:30
369548	DRAIN:CLEAR BLOCKAGE TO GULLY/DRAIN	26.26	50	0.83	0.7	0:42:34	1.19	SLO001	00:16:09	00:01:17	00:25:08	Friday	GRD047	20/12/2013 14:19
370289	BASIN:CLEAR BLOCKAGE	32.04	50	0.83	0.45	0:27:25	1.85	THO019	00:06:23	00:00:54	00:20:08	Monday	PLU002	06/01/2014 15:17
370128	SHOWER:CLEAR BLOCKAGE INCLUDING REMOVE	39.85	75	1.25	1.3	1:18:35	0.96	MIL026	00:18:28	00:01:06	00:59:01	Monday	PLU034	06/01/2014 15:50
371054	DRAIN:CLEAR BLOCKAGE TO GULLY/DRAIN	26.26	50	0.83	1.58	1:35:06	0.53	MIL026	00:06:40	00:07:30	01:20:56	Wednesday	GRD047	08/01/2014 11:30
370863	SINK:CLEAR BLOCKAGE	32.04	50	0.83	0.43	0:26:28	1.94	THO019	00:09:58	00:00:26	00:16:04	Wednesday	PLU046	15/01/2014 10:34
370286	BASIN:CLEAR BLOCKAGE	32.04	50	0.83	0.55	0:33:27	1.52	SLO001	00:19:03	00:00:27	00:13:57	Thursday	PLU002	16/01/2014 10:29
371988	DRAIN:CLEAR BLOCKAGE TO GULLY/DRAIN	26.26	50	0.83	1.02	1:01:38	0.82	THO019	00:20:16	00:00:29	00:40:53	Monday	GRD047	20/01/2014 11:07
382776	SINK:CLEAR BLOCKAGE	33.16	50	0.83	1.22	1:13:20	0.68	MCG019	00:35:14	00:02:36	00:35:30	Monday	PLU046	27/01/2014 16:09
372071	SINK:CLEAR BLOCKAGE	32.04	50	0.83	0.8	0:48:07	1.04	SLO001	00:15:25	00:11:01	00:21:41	Tuesday	PLU046	28/01/2014 09:07
384168	DRAIN:CLEAR BLOCKAGE TO GULLY/DRAIN	27.18	50	0.83	0.87	0:52:54	0.96	MCG019	00:28:57	00:02:16	00:21:41	Tuesday	GRD047	28/01/2014 16:18
373285	SINK:CLEAR BLOCKAGE	32.04	50	0.83	0.68	0:41:24	1.23	THO019	00:08:46	00:02:37	00:30:01	Wednesday	PLU046	29/01/2014 14:06
373127	BASIN:CLEAR BLOCKAGE	32.04	50	0.83	2.17	2:10:01	0.38	SLO001	00:17:42	00:00:24	01:51:55	Wednesday	PLU002	29/01/2014 16:04
373490	SINK:CLEAR BLOCKAGE	32.04	50	0.83	1.15	1:09:15	0.72	THO019	00:04:56	00:00:27	01:03:52	Friday	PLU046	31/01/2014 15:17
376488	BASIN:CLEAR BLOCKAGE	32.04	50	0.83	1.85	1:51:02	0.45	MCG019	00:44:32	00:03:49	01:02:41	Monday	PLU002	03/02/2014 15:18
373562	SINK:CLEAR BLOCKAGE	32.04	50	0.83	1	1:00:25	0.83	SLO001	00:05:55	00:01:34	00:52:56	Thursday	PLU046	06/02/2014 13:39
374136	DRAIN:CLEAR BLOCKAGE TO GULLY/DRAIN	26.26	50	0.83	1.03	1:02:17	0.81	MCG019	00:48:10	00:01:49	00:12:18	Thursday	GRD047	06/02/2014 14:06

374319	SHOWER:CLEAR BLOCKAGE INCLUDING REMOVE	39.85	75	1.25	0.57	0:34:31	2.19	SLO001	00:08:16	00:02:57	00:23:18	Friday	PLU034	07/02/2014 10:34
371271	BASIN:CLEAR BLOCKAGE	32.04	50	0.83	2.73	2:44:27	0.31	MIL026	00:33:14	00:00:45	02:10:28	Friday	PLU002	07/02/2014 10:51
374435	DRAIN:CLEAR BLOCKAGE TO GULLY/DRAIN	26.26	50	0.83	0.62	0:37:07	1.34	SLO001	00:11:19	00:12:09	00:13:39	Friday	GRD047	07/02/2014 13:33
373975	SINK:CLEAR BLOCKAGE	32.04	50	0.83	1.3	1:18:44	0.64	MCG019	00:25:15	00:06:26	00:47:03	Friday	PLU046	07/02/2014 13:45
374484	BATH:CLEAR BLOCKAGE TO WASTE	32.04	50	0.83	0.73	0:44:16	1.14	SLO001	00:20:07	00:13:37	00:10:32	Tuesday	PLU008	11/02/2014 08:13
382922	SINK:CLEAR BLOCKAGE	33.16	50	0.83	1.87	1:52:12	0.45	HUT005	00:36:16	00:07:02	01:08:54	Wednesday	PLU046	12/02/2014 12:28
374560	SINK:CLEAR BLOCKAGE	32.04	50	0.83	0.3	0:18:43	2.78	SLO001	00:05:12	00:04:05	00:09:26	Thursday	PLU046	13/02/2014 09:51
373794	SINK:CLEAR BLOCKAGE	32.04	50	0.83	0.8	0:48:33	1.04	THO019	00:09:38	00:00:30	00:38:25	Friday	PLU046	14/02/2014 12:00
374754	DRAIN:CLEAR BLOCKAGE TO GULLY/DRAIN	26.26	50	0.83	0.73	0:44:18	1.14	THO019	00:00:04	00:00:23	00:43:51	Friday	GRD047	14/02/2014 12:45
373982	BASIN:CLEAR BLOCKAGE	32.04	50	0.83	0.67	0:40:55	1.24	MIL026	00:05:24	00:02:20	00:33:11	Monday	PLU002	17/02/2014 11:55
374952	BATH:CLEAR BLOCKAGE TO WASTE	32.04	50	0.83	0.52	0:31:06	1.60	SLO001	00:20:06	00:01:54	00:09:06	Monday	PLU008	17/02/2014 14:30
375212	SINK:CLEAR BLOCKAGE	32.04	50	0.83	1.92	1:55:59	0.43	SLO001	00:10:01	00:00:37	01:45:21	Monday	PLU046	17/02/2014 16:32
374309	SINK:CLEAR BLOCKAGE	32.04	50	0.83	1.08	1:05:44	0.77	MCG019	00:26:47	00:05:09	00:33:48	Tuesday	PLU046	18/02/2014 11:57
375291	DRAIN:CLEAR BLOCKAGE TO GULLY/DRAIN	26.26	50	0.83	1	1:00:25	0.83	MCG019	00:05:12	00:02:38	00:52:35	Tuesday	GRD047	18/02/2014 14:35
375218	BASIN:CLEAR BLOCKAGE	32.04	50	0.83	0.98	0:59:27	0.85	SLO001	00:11:44	00:03:33	00:44:10	Tuesday	PLU002	18/02/2014 16:02
375434	BASIN:CLEAR BLOCKAGE	32.04	50	0.83	0.73	0:44:22	1.14	SLO001	00:28:18	00:14:25	00:01:39	Friday	PLU002	21/02/2014 08:19
375717	SINK:CLEAR BLOCKAGE	32.04	50	0.83	1.15	1:09:45	0.72	HUT005	00:21:23	00:16:18	00:32:04	Thursday	PLU046	27/02/2014 10:45
377918	BASIN:CLEAR BLOCKAGE	32.04	50	0.83	2.07	2:04:56	0.40	SLO001	00:11:31	00:01:03	01:52:22	Thursday	PLU002	27/02/2014 12:58
375062	DRAIN:CLEAR BLOCKAGE TO GULLY/DRAIN	26.26	50	0.83	0.72	0:43:07	1.16	THO019	00:24:43	00:00:23	00:18:01	Tuesday	GRD047	04/03/2014 11:05
373255	BATH:CLEAR BLOCKAGE TO WASTE	32.04	50	0.83	1.75	1:45:44	0.48	MCG019	00:00:02	00:11:57	01:33:45	Tuesday	PLU008	04/03/2014 11:06
376501	DRAIN:CLEAR BLOCKAGE TO GULLY/DRAIN	26.26	50	0.83	1.42	1:25:13	0.59	THO019	00:15:19	00:01:53	01:08:01	Thursday	GRD047	06/03/2014 16:17
381187	BASIN:CLEAR BLOCKAGE	33.16	50	0.83	1.77	1:46:23	0.47	MCG019	00:32:49	00:05:19	01:08:15	Monday	PLU002	10/03/2014 16:08
377108	SINK:CLEAR BLOCKAGE	32.04	50	0.83	1.12	1:07:27	0.74	MCG019	00:09:54	00:57:03	00:00:30	Tuesday	PLU046	11/03/2014 16:00
377390	BASIN:CLEAR BLOCKAGE	32.04	50	0.83	0.93	0:56:53	0.90	HUT005	00:19:52	00:12:29	00:24:32	Wednesday	PLU002	12/03/2014 08:47
378695	BATH:CLEAR BLOCKAGE TO WASTE	32.04	50	0.83	0.85	0:51:25	0.98	HUT005	00:10:54	00:05:21	00:35:10	Thursday	PLU008	13/03/2014 13:22
376968	SINK:CLEAR BLOCKAGE	32.04	50	0.83	0.93	0:56:45	0.90	THO019	00:13:06	00:02:00	00:41:39	Friday	PLU046	14/03/2014 15:20
377777	BASIN:CLEAR BLOCKAGE	32.04	50	0.83	0.98	0:59:03	0.85	THO019	00:06:22	00:01:57	00:50:44	Monday	PLU002	17/03/2014 16:16
375680	SINK:CLEAR BLOCKAGE	32.04	50	0.83	1.33	1:20:02	0.63	SLO001	00:30:21	00:05:25	00:44:16	Tuesday	PLU046	18/03/2014 09:54
377944	SINK:CLEAR BLOCKAGE	32.04	50	0.83	0.65	0:39:13	1.28	THO019	00:12:40	00:02:06	00:24:27	Wednesday	PLU046	19/03/2014 12:28

378091	SHOWER:CLEAR BLOCKAGE INCLUDING REMOVE	39.85	75	1.25	1.28	1:17:31	0.98	MIL026	00:07:48	00:00:20	01:09:23	Friday	PLU034	21/03/2014 12:27
378174	DRAIN:CLEAR BLOCKAGE TO GULLY/DRAIN	26.26	50	0.83	0.57	0:34:50	1.46	MIL026	00:32:48	00:00:29	00:01:33	Friday	GRD047	21/03/2014 13:14
375344	DRAIN:CLEAR BLOCKAGE TO GULLY/DRAIN	26.26	50	0.83	0.52	0:31:51	1.60	MCG019	00:10:37	00:00:15	00:20:59	Monday	GRD047	24/03/2014 16:09
381263	BASIN:CLEAR BLOCKAGE	33.16	50	0.83	2.6	2:36:25	0.32	HUT005	00:38:25	00:06:00	01:52:00	Tuesday	PLU002	25/03/2014 14:51
378575	BATH:CLEAR BLOCKAGE TO WASTE	32.04	50	0.83	0.88	0:53:17	0.95	HUT005	00:23:14	00:00:17	00:29:46	Wednesday	PLU008	26/03/2014 16:02
378333	BATH:CLEAR BLOCKAGE TO WASTE	32.04	50	0.83	0.28	0:17:27	2.98	MIL026	00:10:07	00:00:20	00:07:00	Thursday	PLU008	27/03/2014 12:38
378785	BATH:CLEAR BLOCKAGE TO WASTE	32.04	50	0.83	0.37	0:22:20	2.25	MIL026	00:13:40	00:06:05	00:02:35	Tuesday	PLU008	01/04/2014 15:34
378516	BASIN:CLEAR BLOCKAGE	32.04	50	0.83	0.43	0:26:22	1.94	MCG019	00:16:55	00:07:11	00:02:16	Wednesday	PLU002	02/04/2014 08:38
384269	BASIN:CLEAR BLOCKAGE	33.16	50	0.83	0.35	0:21:19	2.38	MCG019	00:02:26	00:09:14	00:09:39	Wednesday	PLU002	02/04/2014 09:00
379232	BASIN:CLEAR BLOCKAGE	32.04	50	0.83	0.6	0:36:43	1.39	MCG019	00:05:49	00:01:40	00:29:14	Wednesday	PLU002	02/04/2014 11:43
374880	BASIN:CLEAR BLOCKAGE	32.04	50	0.83	0.97	0:58:43	0.86	HUT005	00:26:57	00:06:13	00:25:33	Wednesday	PLU002	02/04/2014 12:30
379344	BASIN:CLEAR BLOCKAGE	32.04	50	0.83	1.25	1:15:41	0.67	MCG019	00:13:31	00:03:13	00:58:57	Friday	PLU002	04/04/2014 10:42
379240	DRAIN:CLEAR BLOCKAGE TO GULLY/DRAIN	26.26	50	0.83	0.83	0:50:10	1.00	MCG019	00:11:06	00:01:28	00:37:36	Friday	GRD047	04/04/2014 14:03
379690	SINK:CLEAR BLOCKAGE	32.04	50	0.83	1.15	1:09:31	0.72	BRA011	00:21:20	00:06:25	00:41:46	Monday	PLU046	07/04/2014 14:48
377400	DRAIN:CLEAR BLOCKAGE TO GULLY/DRAIN	26.26	50	0.83	1.93	1:56:49	0.43	HUT005	00:37:44	00:11:50	01:07:15	Tuesday	GRD047	08/04/2014 09:22
379713	SINK:CLEAR BLOCKAGE	32.04	50	0.83	0.43	0:26:05	1.94	BRA011	00:02:23	00:06:43	00:16:59	Tuesday	PLU046	08/04/2014 10:03
379779	SINK:CLEAR BLOCKAGE	32.04	50	0.83	0.6	0:36:32	1.39	BRA011	00:11:46	00:00:17	00:24:29	Tuesday	PLU046	08/04/2014 11:01
379847	DRAIN:CLEAR BLOCKAGE TO GULLY/DRAIN	26.26	50	0.83	1.27	1:16:22	0.66	BRA011	00:04:59	00:12:28	00:58:55	Wednesday	GRD047	09/04/2014 11:45
379913	DRAIN:CLEAR BLOCKAGE TO GULLY/DRAIN	26.26	50	0.83	1.25	1:15:43	0.67	BRA011	00:23:13	00:17:37	00:34:53	Thursday	GRD047	10/04/2014 08:56
379946	DRAIN:CLEAR BLOCKAGE TO GULLY/DRAIN	26.26	50	0.83	1.05	1:03:53	0.79	BRA011	00:18:29	00:14:22	00:31:02	Thursday	GRD047	10/04/2014 13:11
380139	BATH:CLEAR BLOCKAGE TO WASTE	33.16	50	0.83	0.18	0:11:19	4.63	BRA011	00:00:04	00:00:18	00:10:57	Friday	PLU008	11/04/2014 13:56
380366	SINK:CLEAR BLOCKAGE	33.16	50	0.83	0.72	0:43:10	1.16	BRA011	00:17:17	00:25:21	00:00:32	Tuesday	PLU046	15/04/2014 14:50

APPENDIX C7 – Joinery Task Comparison Data

IRONMONGERY/FITTINGS

HMS				CDRMS			
Order Number	PI EH HMS	Operative ID		Job No.	PI EH	PI EH (SMV)	Tradesmen
368268	3.62	MCF012		L38177	3.00	1.666	2008
368170	3.79	TRE002		L49487	0.60	0.5	1417,1411
369045	0.90	TRE002		L55866	0.77	0.43	2400
369011	0.91	LEE003		L50546	0.82	0.82	2400
369457	2.38	TRE002		L56732	0.98	0.82	2400
370750	1.44	WIL020		L56732	0.98	0.82	2400
372570	1.87	MCF012		L58341	1.47	1.23	2400
372645	2.02	MCF012		L58219	0.75	0.42	2008
372671	1.42	WIL020		L59201	2.00	1.25	2008
372279	0.88	TRE002		L58393	1.25	1.25	2031
372883	2.91	MCF012		L58859	4.00	2.50	2339
371961	0.42	MAC036		L58904	1.23	0.82	2400
373156	0.71	LUS002		L58419	1.47	1.23	2400
372454	2.60	MCF012		L58379	1.47	1.23	2400
372711	0.98	MAC036		L58931	1.00	0.83	2042
373854	1.28	WIL020		L58203	1.33	0.83	2023
373858	0.91	HOW005		L59841	1.19	1.19	2015
373723	0.59	WIL020		L55300	0.50	0.28	2327
373931	0.88	WIL020		L58439	1.00	0.63	2035
373373	0.71	STA005		L58888	1.25	0.83	2042
374034	0.71	WIL020		L60172	1.25	0.83	2075,2076
374150	1.00	MCF012		L54483	1.67	1.67	1411
374162	1.34	LEE003		L60243	1.00	0.63	2075,2076
374389	2.19	KEA003		L59244	1.82	1.14	2302
374539	0.77	MCF012		L59673	1.25	1.25	2031
375147	0.96	KEA003		L58945	0.63	0.63	2049
375120	0.71	LUS002		L53171	1.50	0.83	1411
375366	1.98	WIL020		L56271	2.00	1.67	1411
375541	1.02	TRE002		L57379	0.5	0.21	2340,2459
375651	1.21	TRE002		L58804	2.05	0.85	2049
375500	1.34	WIL020		L59244	4.00	2.5	2301
375386	1.77	WIL020		L58848	2.00	1.25	2034
375883	1.98	TRE002		L60355	2.00	1.25	2021
375717	0.17	MAC036		L57362	1.33	0.83	2339
375957	2.40	LEE003		L59288	1.53	1.28	2034
376438	1.25	LUS002		L60954	1.28	1.28	2015
375435	1.39	WIL020		L60856	4.00	2.50	2301
376556	0.60	BUR011		L60888	2.67	1.67	2339
376592	3.79	WIL020		L60353	0.63	0.63	2023
376615	2.78	MCF012		L60692	0.75	0.42	2038
376651	1.00	LUS002		L60479	0.67	0.42	2031
376688	0.53	MCF012		L61223	1.50	0.83	2038
376949	2.60	MCF012		L60878	0.75	0.42	2031
376965	1.23	MAC036		L59919	4.00	0.42	2043
376558	3.38	WIL020		L54694	0.75	0.42	20,422,003
377278	1.74	MAC036		L61245	0.83	0.83	2044
377216	1.39	WIL020		L59917	1.50	1.25	2023
377765	1.74	WIL020		L61130	1.25	1.25	2043
377491	1.32	WIL020		L56666	2.00	1.11	1411
377660	1.14	BUR011		L60597	1.33	0.56	2043
377859	1.60	MCF012		L60600	1.33	0.56	2043
377980	2.04	WIL020		L61503	1.90	1.19	2083
377884	2.60	WIL020		L61573	1.90	1.19	2036
377970	0.96	BUR011		L71756	0.38	0.31	2003,2043
377923	1.02	MAC036		L86594	1.50	1.25	2015
378122	1.98	WIL020		L87399	2.50	2.50	2015
378233	1.23	MCF012		L87399	2.50	2.50	2015
378498	2.36	WIL020		L87458	1.00	0.83	2044
378927	1.39	WIL020		L86944	1.50	1.25	2075,2076
378578	0.83	WIL020		L72303	3.00	2.50	1411

379159	0.98	WIL020		L80591	1.00	0.83	1411
379138	1.92	MCF012		L89266	1.50	1.25	2042
379118	1.34	STA005		L81592	1.00	0.83	1411
379172	1.92	MAC036		L87664	1.50	1.25	1411
379779	3.91	MCF012		L88064	1.00	0.83	1411
378261	0.37	MCF012		L88233	1.19	1.19	2015
377173	0.62	WIL020		L88233	1.19	1.19	2015
380129	0.98	WIL020		L87713	2.00	1.67	2301
379889	0.55	WIL020		L80348	0.85	0.71	1411,6014
380155	4.17	WIL020		L85939	0.82	0.82	2015
379737	0.40	LUS002		L88320	1.42	1.19	2015
379982	1.02	TRE002		L88265	0.83	0.83	1411
380137	0.85	WIL020		L88185	1.50	1.25	2034
380460	0.63	WIL020		L87747	1.50	1.50	2043
379696	3.79	WIL020		L81056	0.59	0.33	2015,7015
380765	1.98	WIL020		L84902	1.00	0.83	1411
380903	2.78	TRE002		L85909	1.50	1.25	1411
380824	0.83	MCL018		L88589	1.00	0.83	1411
380912	3.62	TRE002		L89128	1.42	1.19	2026
380930	1.84	HEA002		L88208	1.50	1.25	2075,2076
381347	0.75	TRE002		L77818	0.75	0.63	2021
381379	0.53	WIL020		L77824	1.25	1.25	2021
380992	0.77	STA005		L82118	0.83	0.83	1411
381533	0.76	KEA003		L86178	0.54	0.45	2015,7015
381521	0.57	MAC036		L84264	1.25	1.25	1411
381909	1.39	WIL020		L85959	1.50	1.25	1411
382345	1.44	WIL020		L88440	2.00	1.67	1411
382089	1.14	WIL020		L88501	2.86	2.86	1411
382009	0.33	TRE002		L88645	1.00	0.56	1411
382590	0.44	WIL020		L88657	1.22	1.02	2003,2003
382758	2.08	STA005		L89298	1.53	1.28	2042
382715	3.57	HOW005		L89600	1.19	1.19	2343
382905	0.20	HOW005		L77639	1.00	0.83	2023
382725	0.81	BUR011		L87150	1.00	0.83	2044
383415	1.14	HOW005		L77765	1.00	1.25	2015
383823	0.28	WIL020		L77769	1.00	1.25	2015
383853	3.33	WIL020		L77810	1.00	1.25	2015
383713	1.17	WIL020		L78103	1.50	1.25	2015
384032	2.78	WIL020		L78109	4.00	2.50	2015
384028	1.00	HOW005		L80882	2.00	1.25	2015
384097	1.47	MCF012		L82457	2.00	2.50	2015
383186	1.39	TRE002		L80475	4.00	2.50	2076,2075
384259	4.43	WIL020		L80572	3.00	2.50	2038
384421	0.60	WIL020		L80258	1.20	1.00	2043
384089	1.23	TRE002		L87086	2.00	1.25	2339
382902	0.31	WIL020		L87087	2.00	1.25	2041

APPENDIX C8 – Electrical Task Comparison Data

Lighting Repairs

HMS				CDRMS			
Order Number	PI EH HMS	Operative ID		Job No.	PI EH	PI EH (SMV)	Tradesman
367885	0.69	BIG001		L58829	0.50	0.42	6060,6076
367929	1.77	HEA002		L38334	2	1.66	6078
367941	1.14	HEA002		L50502	4	3.32	6046
367926	1.11	HEA002		L50844	4	3.32	6046
366574	1.74	HEA002		L50416	4.3	3.6	6046
367993	1.11	HEA002		L54090	0.8	0.664	6072,6020
367983	1.34	HEA002		L45719	0.4	0.332	6060, 6076
368068	1.26	HEA002		L53443	0.6	0.8	6008,6014
367942	1.39	HEA002		L52166	1.2	1.7	6073,6073
368021	1.19	HEA002		L52110	0.6	0.8	6073,6073
368184	2.08	HEA002		L58397	1	0.83	6020
368111	2.98	BIG001		L56375	1	0.83	6213
368074	0.93	BIG001		L56988	1	0.83	6060,6076
368142	2.27	BIG001		L58086	1.3	1.1	6002
368293	1.81	BIG001		L57096	0.7	0.8	6213
368270	2.19	BIG001		L55956	1.3	1.1	6002
368398	2.98	BIG001		L57815	0.8	0.664	6002
368440	0.96	BIG001		L56955	1	0.83	6060,6076
368448	0.80	HEA002		L56190	1	0.83	6060,6076
368223	1.11	BIG001		L58642	2	1.66	6014
368430	3.79	BIG001		L58140	2	1.66	6014
368491	4.90	BIG001		L58455	2	1.66	6008
368565	1.19	HEA002		L56501	1	0.83	6060,6076
368484	0.95	BIG001		L54107	0.7	0.6	6060,6076
368582	4.17	BIG001		L55923	1	0.83	6060,6076
368496	1.89	BIG001		L51402	1.8	2.5	6016
368344	1.28	HEA002		L53476	3.5	5	6014
368538	0.83	HEA002		L55763	1	0.83	6060,6076
368506	1.98	BIG001		L52549	1.3	1.1	6002
368156	3.79	BIG001		L56344	1	0.83	6060,6076
368954	1.98	HEA002		L54793	1.3	1.1	6002
368841	0.85	HEA002		L58617	1.3	1.1	6008
369007	4.63	BIG001		L56601	0.3	0.3	6060,6076
369169	1.02	HEA002		L58800	1.3	1.1	6008
368879	1.11	HEA002		L57425	0.7	0.6	6213
369142	4.17	BIG001		L56333	0.4	0.332	6060,6076
369034	1.46	BIG001		L59006	1.3	1.1	6008
368945	0.53	BIG001		L57755	2	1.66	6014
368951	0.78	BIG001		L52234	1	0.83	6060,6076
369246	2.25	BIG001		L58924	1	0.83	6002
368221	1.44	BIG001		L56702	1.3	1.1	6002
369339	1.34	BIG001		L58372	1.3	1.1	6002
369209	3.33	BIG001		L32902	0.7	0.6	6008,6008
368758	0.97	BIG001		L56081	1	0.83	6060,6076
369263	3.09	BIG001		L47885	0.6	0.5	6008
369432	0.87	BIG001		L56562	1.3	1.1	6002
369605	1.28	HEA002		L53137	1.3	1.1	6002
369600	0.95	HEA002		L59094	1.3	1.1	6008
369489	1.77	BIG001		L58717	1.3	1.1	6008
369475	0.63	HEA002		L58280	1	0.83	6002
369306	4.46	BIG001		L55243	0.7	0.6	6002
368266	1.67	HEA002		L58482	1	0.83	6072
369624	2.78	BIG001		L59751	1	1	6020
369644	1.19	BIG001		L59736	1.0	0.8	6020
369775	1.23	HEA002		L59291	1	0.83	6072
369623	4.90	BIG001		L57073	0.5	0.415	6213
369736	3.21	BIG001		L59478	1.3	1.1	6008
369790	1.94	HEA002		L59551	1	0.83	6060,6076
369815	1.52	HEA002		L58142	1.3	1.1	6002

369714	2.98	BIG001		L37425	0.2	0.1	6020
368254	0.97	BIG001		L57395	0.5	0.415	6060,6076
369469	1.23	HAM011		L58447	1	0.83	6060,6076
369630	2.38	BIG001		L59884	0.7	0.6	6060,6076
369301	0.98	HAM011		L45191	0.5	0.415	6016
369837	2.53	HEA002		L59832	1	0.83	6008
369624	0.91	BIG001		L55889	1	0.83	6008,6008
369781	1.94	BIG001		L37657	1.2	1.7	6077
369747	1.54	BIG001		L51481	0.5	0.415	6213,6213
369797	2.08	BIG001		L49467	0.7	0.6	6213
369239	1.51	HEA002		L59149	1	0.83	6085
369624	0.87	BIG001		L57645	0.7	0.6	6213
369932	0.79	BIG001		L59805	1.3	1.1	6008
369902	2.25	BIG001		L55472	3.5	5	6020
369793	0.98	BIG001		L55199	1	0.83	6213
370201	0.53	HEA002		L58913	0.7	0.6	6060,6076
370135	1.34	HEA002		L60367	0.5	0.415	6076,6077
370047	0.80	BIG001		L60406	2	1.66	6008
370015	2.25	BIG001		L60627	1	0.83	6020
370047	1.04	BIG001		L57441	0.7	0.6	6016
370036	0.83	BIG001		L56490	1	0.83	6060,6076
370065	2.25	BIG001		L58965	1	0.83	6060,6076
370398	1.77	HEA002		L58858	2	1.66	6020
370065	0.89	BIG001		L60046	1.3	1.1	6008
370546	1.98	HEA002		L57310	0.5	0.415	6016
370284	2.98	BIG001		L46837	0.5	0.415	6004,6216
370520	4.63	HEA002		L52678	1.8	2.5	6002
370691	0.85	HEA002		L58177	1	0.83	6060,6076
370653	1.14	HAM011		L60381	1.3	1.1	6072
370611	1.94	BIG001		L58256	1	1	6002
370795	0.96	HAM011		L60058	1	1	6008
370777	0.64	HEA002		L54999	0.7	0.6	6213
370644	0.70	BIG001		L60292	1.3	1.1	6008
370781	1.54	BIG001		L38055	1	0.83	6085
370875	2.08	BIG001		L60193	1.3	1.1	6008
371094	0.56	YOU008		L56572	1	0.83	6077
371031	4.17	BIG001		L58824	1.3	1.1	6020
371097	0.54	YOU008		L57275	1.3	1.1	6002
371157	1.46	HEA002		L60139	1.3	1.1	6008
370866	1.67	BIG001		L59519	2	1.66	6020
371305	0.68	HEA002		L32884	1	1.4286	6011,6002
371253	1.60	HEA002		L60308	2	1.66	6014
370896	1.85	BIG001		L59255	1.3	1.1	6002
371251	1.19	HEA002		L61048	1.3	1.1	6002
370807	1.00	BIG001		L61052	1	0.83	6002
370853	0.96	BIG001		L59150	1.3	1.1	6020
370377	3.33	BIG001		L60305	2	1.66	6008
371096	0.37	YOU008		L60333	1	0.83	6076,6077
371186	0.95	HEA002		L60629	1	0.83	6076,6077
371122	1.13	BIG001		L59582	1.3	1.1	6014
371281	2.78	HEA002		L60693	1	0.83	6020
371189	0.35	BIG001		L55912	1.8	2.5	6076,6077
371258	0.91	HEA002		L58743	1.3	1.1	6002
371129	1.67	BIG001		L59521	1.3	1.1	6072
371100	0.56	YOU008		L59979	1.3	1.1	6008
371484	0.51	HEA002		L61168	0.8	0.664	6072
371464	1.46	HEA002		L61238	1.3	1.1	6020
370757	1.24	BIG001		L59272	1.3	1.1	6002
371579	0.47	HEA002		L60748	1	0.83	6076,6077
371296	1.67	BIG001		L61526	1	1	6085
371722	1.81	HEA002		L61523	1	1	6085
371774	0.88	HEA002		L77859	2.00	1.66	6008

APPENDIX C9 – Plumbing Tasks Comparison Data

		CLEAR CHOKE REPAIRS					
HMS				CDRMS			
Order Number	PI EH HMS	Operative ID		Job No.	PI EH	PI EH SMV	Tradesman
384099	1.34	SLO001		L07463	2.5	1.66	4208
367382	0.71	SLO001		L20815	1.25	0.83	4208
367961	2.50	SLO001		L25865	2.5	2.50	4208
376082	0.65	THO019		L50404	3	1.66	4208
384170	1.08	SLO001		L58781	0.83	0.55	4013
369131	1.34	THO019		L58578	0.43	0.28	4013,2044
381030	2.60	MIL026		L58958	1.25	0.83	4208
369948	0.98	THO019		L59613	1.25	0.83	4013
369548	1.19	SLO001		L59988	1	0.79	4009
370289	1.85	THO019		L59396	1	0.83	4017
370128	0.96	MIL026		L59360	1.25	1.25	4208
371054	0.53	MIL026		L59247	1.25	0.83	4208
370863	1.94	THO019		L59602	1	0.83	4208
370286	1.52	SLO001		L59104	1.25	0.83	4017
371988	0.82	THO019		L59899	1	0.79	4009
382776	0.68	MCG019		L59717	1.25	0.83	4208
372071	1.04	SLO001		L60349	1.67	1.11	4028
384168	0.96	MCG019		L59675	0.83	0.55	4208,4208
373285	1.23	THO019		L60595	1.25	0.83	4208
373127	0.38	SLO001		L60593	1.67	1.11	4028
373490	0.72	THO019		L61019	0.79	0.53	4039
376488	0.45	MCG019		L59579	0.79	0.53	4016
373562	0.83	SLO001		L60922	0.89	0.59	4039
374136	0.81	MCG019		L60637	1.25	0.83	4208
374319	2.19	SLO001		L60625	0.63	0.42	4017
371271	0.31	MIL026		L60886	1.3	0.83	4016
374435	1.34	SLO001		L61061	2.5	1.66	4208
373975	0.64	MCG019		L61469	1	0.79	4014
374484	1.14	SLO001		L61074	1.25	0.83	4208
382922	0.45	HUT005		L61206	1	0.79	4014
374560	2.78	SLO001		L61077	1	0.83	4017
373794	1.04	THO019		L61433	1	0.79	4014
374754	1.14	THO019		L61300	1	0.79	4010
373982	1.24	MIL026		L61502	1	0.79	4010
374952	1.60	SLO001		L61480	1	0.79	4010
375212	0.43	SLO001		L61491	1	0.79	4010
374309	0.77	MCG019		L61483	1	0.79	4010
375291	0.83	MCG019		L61145	1	0.79	4010
375218	0.85	SLO001		L61414	1	0.79	4010
375434	1.14	SLO001		L61605	1	0.79	4016
375717	0.72	HUT005		L61562	1	0.79	4016
377918	0.40	SLO001		L61570	1	0.79	4016
375062	1.16	THO019		L61580	1	0.79	4016
373255	0.48	MCG019		L75587	2.50	1.66	4009
376501	0.59	THO019		L76915	2.50	1.66	4037
381187	0.47	MCG019		L77004	2.50	2.50	4208
377108	0.74	MCG019		L77987	0.45	0.30	1590
377390	0.90	HUT005		L78035	1.30	0.86	1590,4028
378695	0.98	HUT005		L79407	2.50	1.66	4208
376968	0.90	THO019		L86200	1.25	0.83	4208
377777	0.85	THO019		L87385	1.25	1.25	4006
375680	0.63	SLO001		L87426	1.25	1.25	4006
377944	1.28	THO019		L87441	1.00	0.66	4013
378091	0.98	MIL026		L87396	0.50	0.33	4016
378174	1.46	MIL026		L87486	1.67	1.11	4028

375344	1.60	MCG019		L87498	0.29	0.20	4028,4013
381263	0.32	HUT005		L87395	1.25	0.83	4208
378575	0.95	HUT005		L87816	1.19	0.79	4208
378333	2.98	MIL026		L87826	1.19	0.79	4208
378785	2.25	MIL026		L88176	1.25	0.83	4009
378516	1.94	MCG019		L88014	0.64	0.42	1590,4013
384269	2.38	MCG019		L87885	0.63	0.42	4006
379232	1.39	MCG019		L87787	1.25	1.25	4009
374880	0.86	HUT005		L87986	1.25	0.83	4009
379344	0.67	MCG019		L87801	2.50	1.66	4017
379240	1.00	MCG019		L87961	1.25	0.83	4028
379690	0.72	BRA011		L88015	1.67	1.11	4028
377400	0.43	HUT005		L88210	0.79	0.53	4033
379713	1.94	BRA011		L88028	1.25	0.83	4208
379779	1.39	BRA011		L88133	1.25	0.83	4208
379847	0.66	BRA011		L88452	0.83	0.55	4009
379913	0.67	BRA011		L88319	0.45	0.30	4013
379946	0.79	BRA011		L88530	2.50	1.66	4017
380139	4.63	BRA011		L88420	1.67	1.11	4028
380366	1.16	BRA011		L88838	2.50	2.50	4017
379613	2.98	MIL026		L88844	0.83	0.55	4006
380221	0.68	BRA011		L88851	1.25	0.83	4006
380330	0.90	MIL026		L88944	1.25	0.83	4006
379573	1.00	MCG019		L88740	1.25	0.83	4013
379675	0.53	HUT005		L88828	0.83	0.55	4017
379519	0.74	MCG019		L88864	2.50	1.66	4017
379070	1.08	HUT005		L89181	0.52	0.34	1590,4017
381260	1.52	BRA011		L89165	0.83	0.55	4013
373442	0.41	HUT005		L89297	1.67	1.11	4016
381846	1.74	BRA011		L89357	1.67	1.11	4016
377323	2.53	MCG019		L89360	1.67	1.11	4016
382313	1.11	BRA011		L89286	2.50	1.66	4017
382351	1.23	BRA011		L89163	1.25	0.83	4028
382527	2.25	BRA011		L89336	2.50	1.66	4028
382376	0.77	BRA011		L89425	1.19	0.79	4037
381516	0.66	HUT005		L89553	1.19	0.79	4037
383939	1.04	GIB010		L89564	1.19	0.79	4037
381033	0.79	MIL026		L89307	1.25	0.83	4208
382527	0.54	BRA011		L89340	1.25	1.25	4208
383641	1.24	BRA011		L89431	0.63	0.42	1590,4061
383272	0.57	BRA011		L89432	0.63	0.42	1590,4061
383280	0.74	BRA011		L89581	0.50	0.33	1590,4061
383934	0.83	HUT005		L89446	1.19	1.19	4061
381976	0.88	MCG019		L89513	1.19	1.19	4061
383778	1.44	MCG019		L89573	1.19	0.79	4061
368345	3.33	MIL026		L89602	1.19	0.79	4061